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March 1983

INITIAL ASSESSMENT STUDY OF NAVAL WEAPONS INDUSTRIAL RESERVE PLANT, MCGREGOR, TEXAS

NEESA 13-006

NAVAL ENERGY AND ENVIRONMENTAL SUPPORT ACTIVITY
Port Hueneme, California 93043

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PORT HUENEME, CALIFORNIA 93043

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From: Commanding Officer, Naval Energy and Environmental Support Activity
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Subj: Initial Assessment Study of the Naval Weapons Industrial Reserve Plant, McGregor, Texas, NEESA 13-006

Ref: (a) OPNAVNOTE 6240 ser 45/733503 of 11 Sep 80
(b) MARCORPS Order 6280.1 of 30 Jan 81
(c) COMNAVFACENGCOM ltr 1121B/PAP of 5 Jun 81
(d) OIC NAVENENVSA ltr 112N:JCH:pm ser 907 of 26 Jun 81

Encl: (1) Initial Assessment Study of the Naval Weapons Industrial Reserve Plant
(2) Summary of recommended actions

1. The Navy Assessment and Control of Installation Pollutants (NACIP) program was authorized by references (a) and (b). This program provides for identification, assessment, and control of environmental contamination from past storage, use, and disposal of chemicals and hazardous materials at Navy and Marine Corps activities. Under NACIP, the Naval Energy and Environmental Support Activity (NEESA) conducts an Initial Assessment Study at an activity to ascertain the potential for environmental contamination. If the potential for contamination is found to exist at an activity, a confirmation study and, if required, projects for corrective measures will be initiated by the EFD. An Initial Assessment Study for the Naval Weapons Industrial Reserve Plant, McGregor Texas, was approved by the Chief of Naval Operations in reference (c). The study was initiated by NEESA in reference (d).

2. Enclosure (1), the Initial Assessment Study of Naval Weapons Industrial Reserve Plant, McGregor, Texas, NEESA 13-006, was prepared for NEESA by Envirodyne Engineers, Inc., of St. Louis, Missouri. Seven potentially contaminated sites were recommended for confirmation study, phase II of the NACIP program. A summary of recommended actions is included as enclosure (2). The confirmation study consists of a field investigation, including detailed physical and analytical monitoring, to confirm or deny the presence of any contamination or a health hazard and to quantify the extent of any problem that may exist.

3. Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM), will administer and coordinate all further actions of the NACIP program. SOUTHNAVFACENGCOM will initiate the confirmation study using pollution abatement funds. The point of contact for the confirmation study is Dick Bozung, SOUTHNAVFACENGCOM 114, AUTOVON 794-5510, FTS 679-5510, or (803) 743-5510.

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4. Questions concerning the Initial Assessment Study may be referred to the undersigned or Jeffery C. Heath, NEESA 112N, AUTOVON 360-3351, FTS 799-3351 or (805) 982-3351.

DANIEL L. SPIEGELBERG
By direction

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Summary of Recommended Actions

An Initial Assessment Study (IAS) was conducted at Naval Weapons Industrial Reserve Plant (NWIRP) McGregor, Texas. The purpose of the study is to identify and assess sites posing a potential threat to human health or the environment due to contamination from past hazardous materials operations. Based on information from historical records, aerial photographs, field inspections, and personnel interviews, a total of 14 potentially contaminated sites were identified at NWIRP McGregor.

The 14 sites identified by the IAS team were evaluated using a Confirmation Study Ranking System (CSRS) developed by NEESA for the NACIP program. The system is a two step procedure for systematically evaluating a site's potential hazard to human health and the environment, based on evidence collected during the IAS.

Step one of the system is a flow chart which eliminates innocuous sites from further consideration. Step two is a ranking model which assigns a numerical score, within a range of 0 to 100, to indicate the potential severity of a site. Scores are a reflection of the characteristics of the wastes disposed of at a site, contaminant migration pathways, and potential contaminant receptors on and off the installation. CSRS scores and engineering judgement are then used to evaluate the need for a confirmation study based on the criteria stipulated in Section 1.3. CSRS scores assigned to sites recommended for confirmation studies also assist Navy managers to establish priorities for accomplishing the recommended actions.

A more detailed description of the Confirmation Study Ranking System is contained in NEESA Report 20.2-042.

Table 1 summarizes the recommended actions and CSRS scores at the 14 potentially contaminated sites at NWIRP McGregor.

ENCLOSURE (2)

Table 1

Summary of Confirmation Study Recommendations

Site Number	Site Name	Further Action Recommended	CSRS[1] Score	No. Wells	No. Soil/ Sediment Samples	No. water Samples	Lab Testing/ Parameters	Remarks
001	Area F--East Settling Ponds	No	-	-	-	-	-	Tetryl, if present, would be detectedin monitoring at Site 002
002	Area F--West Settling Ponds	Yes	15	6	2	8	-	Tetryl, toluene, chlorinated benzenes, TATB, volatile organic analysis, DDT
003	Area F--Stock Pond	Yes	15	-	3	1	-	Analyze for toluene, chlorinated benzenes, TATB, DDT
004	Area E--Dump	No	-	-	-	-	-	
005	Area G--Pesticide Dump	Yes	20	-	126	2	-	Analyze for DDT. Mow area and take aerial photos to find all contaminated areas If soil samples show that DDT is migrating, monitoring wells maybe necessary.
006	Area L--Asbestos Pile	Yes	18	-	-	3	-	Analyze for asbestos. Cover asbestos pile and reroute draining away to prevent erosion of the pile.
007	Area L--TNT Washout Pits	Yes	11	-	-	-	-	Obtain aerial photos from WW II and analyze to see if any washout pits are present. If present, sample the soil and analyze for TNT. (SOUTHDIV has photos)
008	Area M--Interior Settling Basins	No	-	-	-	-	-	
009	Area M--North Pond	Yes	18	-	-	1	-	Analyze for hexavalent chromium and trichloroethylene.
010	Area M--Propellent Washout Pond	No	-	-	-	-	-	
011	Area M--Imhoff Tank and	No	-	-	-	-	-	
012	Area M--TNT Washout Pits	Yes	11	-	-	-	-	Obtain aerial photos from WW II and analyze to see if any washout pits are present. If present, sample the soil and analyze for TNT. (SOUTHDIV has photos)
013	Area S--Burning Grounds	No	-	-	-	-	-	
014	Area S--Landfill	No	-	-	-	-	-	

(1) Sites considered innocuous are eliminated by the Confirmation Study Ranking System (CSRS) and do not receive a score. No further action is needed for those sites.

INITIAL ASSESSMENT STUDY
NAVAL WEAPONS INDUSTRIAL RESERVE PLANT MCGREGOR, TEXAS
UIC: N95918

Prepared by:

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Contract No. N62474-81-C-9385

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Prepared for:

NAVY ASSESSMENT AND CONTROL
OF INSTALLATION POLLUTANTS (NACIP) DEPARTMENT
Naval Energy and Environmental Support Activity (NEESA)
Port Hueneme, California 93043

Project Coordinator

Jeffery C. Heath, P.E.

March 1983

NEPSS

Naval
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Protection
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Service

FOREWORD

The Navy initiated the Navy Assessment and Control of Installation Pollutants (NACIP) program in OPNAVNOTE 6240 ser 45/733503 of 11 September 1980 and Marine Corps Order 6280.1 of 30 January 1981. The purpose of the program is to systematically identify, assess, and control contamination of the environment resulting from past hazardous materials operations.

An Initial Assessment Study (IAS) was performed at the Naval Weapons Industrial Reserve Plant, McGregor, Texas by a team of specialists from Envirodyne Engineers Inc. Further confirmation studies under the NACIP program were recommended at several areas at the activity. Sections dealing with significant findings, conclusions, and recommendations are presented in the earlier sections of the report. The later technical sections provide more in-depth discussion on important aspects of the study.

Questions regarding the NACIP program should be referred to the NACIP Program Director, NEESA 112N, Port Hueneme, California 93043, AUTOVON 360-3351, FTS 799-3351, or commercial (805) 982-3351.

Daniel J Spiegelberg

DANIEL L. SPIEGELBERG, LCDR, CEC, USN
Environmental Officer
Naval Energy and Environmental Support Activity

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ACKNOWLEDGEMENTS

The Initial Assessment Study team commends the support, assistance, and cooperation provided by personnel at Southern Division, Naval Facilities Engineering Command; Naval Energy and Environmental Support Activity; Ordnance Environmental Support Office; and Hercules, Inc. (NWIRP-McGregor). In particular, the team gratefully acknowledges the outstanding effort provided by the following people, who participated in the successful completion of the study:

.George Cobb, Hercules, Inc.

.Harley Kamm, Hercules, Inc.

.Jeff Heath, NEESA

.Liz Luecker, Southern Division, NAVFAC

.Linda Lay, Ordnance Environmental Support Office

Executive Summary

This report presents the results of an Initial Assessment Study (IAS) conducted at Naval Weapons Industrial Reserve Plant (NWIRP) McGregor, Texas. The purpose of an IAS is to identify and assess sites posing a potential threat to human health or the environment due to contamination from past hazardous materials operations.

NWIRP McGregor is underlain by shallow groundwater about 15 feet to 20 feet below the surface. Contaminants, if present, could migrate to the shallow groundwater through vertical cracks in the soil. Presently, this shallow groundwater is used solely for agricultural purposes.

Potable water supply for the area is obtained from the Hensel Aquifer which is located about 1,000 feet beneath the surface. Between the surface and the Hensel Aquifer are many layers of impermeable limestone and shale. The likelihood that this aquifer would become contaminated from activities at NWIRP McGregor is remote.

Based on information from historical records, aerial photographs, field inspections and personnel interviews, a total of fourteen potentially contaminated sites were identified at NWIRP McGregor. Each of the sites was evaluated with regard to contamination characteristics, migration pathways and pollutant receptors.

The study concludes that, while none of the sites pose an immediate threat to human health or the environment, seven sites warrant further investigation under the Navy Assessment and Control of Installation Pollutants (NACIP) Program, to assess potential long-term impacts. A Confirmation Study, involving actual sampling and monitoring of the sites, is recommended to confirm or deny the existence of the suspected contamination and to quantify the extent of any problems which may exist. The seven sites recommended for confirmation are listed below in order of priority:

(1) Area G--Pesticide Dump
(2) Area L--Asbestos Pile
(3) Area M--North Pond
(4) Area F--West Settling Ponds
(5) Area F--Stock Pond
(6) Area L--TNT Washout Pits
(7) Area M--TNT Washout Pits

The results of the Confirmation Study will be used to evaluate the necessity of conducting mitigating actions or clean-up operations.

1.0 INTRODUCTION

As directed by the Chief of Naval Operations, the Naval Energy and Environmental Support Activity (NEESA), in conjunction with the Ordnance Environmental Support Office (OESO), conducts Initial Assessment Studies to ascertain whether or not past operations and disposal practices at Navy shore installations have resulted in environmental contamination. The Initial Assessment Study is the first phase of the NACIP (Navy Assessment and Control of Installation Pollutants) program, which has the objective of identifying, assessing, and controlling environmental contamination from past hazardous materials storage, transfer, manufacturing, and disposal operations. The NACIP program was initiated by OPNAVNOTE 6240 ser 45/733503 of 11 September 1980.

On 22 June 1981, Envirodyne Engineers, Inc. (EEI), St. Louis, Missouri, was contracted by NEESA to conduct an Initial Assessment Study (IAS) of the Naval Weapons Industrial Reserve Plant (NWIRP), McGregor, Texas. From 10 August to 14 August 1981, the on-site portion of the IAS was conducted by a team of four specialists from EEI, who were accompanied by two specialists from NEESA. Prior to performing the on-site survey, EEI compiled and evaluated records from various offices, including the Naval Facilities Engineering Command, the Naval Sea Systems Command, the Navy History Office, the National Archives, and other federal information sources, to obtain documented evidence of environmental contamination. During the on-site survey, the team reviewed activity records and maps, interviewed long-time employees and retirees of NWIRP-McGregor, and physically inspected the activity's facilities and environs. Survey findings and recommended actions are summarized in this report.

A recommendation for the next phase of the NACIP program, the Confirmation Study, is based on the findings of the Initial Assessment Study. A Confirmation Study will be conducted if the following conditions exist:

1. The presence of sufficient evidence to suspect contamination, <u>and</u>

2. The contamination presents a definite danger
   a. To the health of people in adjoining communities and/or within the base fenceline, <u>or</u>

   b. To the environment within and/or outside the installation.

Further studies of the activity under the NACIP program will not be recommended if these criteria are not met.

2.0 SIGNIFICANT FINDINGS

In assessing the NWIRP-McGregor site for areas of contamination and migration potential, numerous significant factors were uncovered. These included several physical features of the site which greatly influence the potential for contamination and migration. In addition, each of the site's operational areas were examined individually in terms of the types of operations, material storage, and waste disposal practices which occurred. This included past as well as present practices. Operational areas not within the present boundaries of the site, but which were within the original boundaries of the Bluebonnet Ordnance Plant, were also evaluated as to their contamination and migration potential. All of the significant findings are discussed in detail in this chapter.

Several physical characteristics of the NWIRP-McGregor site are of particular significance in evaluating the contamination or migration potential. The climatic characteristics of the site are important. Much of the rainfall received at the site occurs from very intense thunderstorms. It is not uncommon for 2 to 4 inches of rain to fall in a matter of hours. Following these intense rainfalls, surface runoff increases dramatically, as does infiltration. The high temperatures and seasonal evaporation rates are also significant.

One of the most important factors is that the soils thoughout the NWIRP-McGregor site are vertisols. When saturated, these soils serve as a very effective barrier to the downward migration of contaminants. This is a result of the high clay content in these soils, which ranges from 35-65 percent. As long as the clay is kept wet, it forms a very impermeable unit. However, when these vertisol soils become dry, which readily occurs in this portion of central Texas, they develop vertical cracks. These cracks can be up to three inches wide and greater than 20 inches deep (see Appendix A). These cracks provide ready access for contaminants to reach the groundwater. A view of the vertisol soils at the site is presented in Plate 2-1.

Also of significance is the shallow groundwater or high water table which occurs throughout the site. The presence of shallow groundwater is verified by the numerous shallow hand-dug wells throughout the site and by the soil boring logs in Appendix A. These records indicate the shallow groundwater is some fifteen to twenty feet below the surface. This makes the presence of vertisol soils even more important, as contaminants could very quickly reach the shallow groundwater through the vertical cracks in the soil. Presently, this shallow groundwater is used solely for agricultural purposes.

It should be pointed out that the water supply for the area is obtained from the Hensel aquifer which is located some 1000 feet beneath the surface. The likelihood that this aquifer would become contaminated from activities at the NWIRP-McGregor site is extremely remote. Between

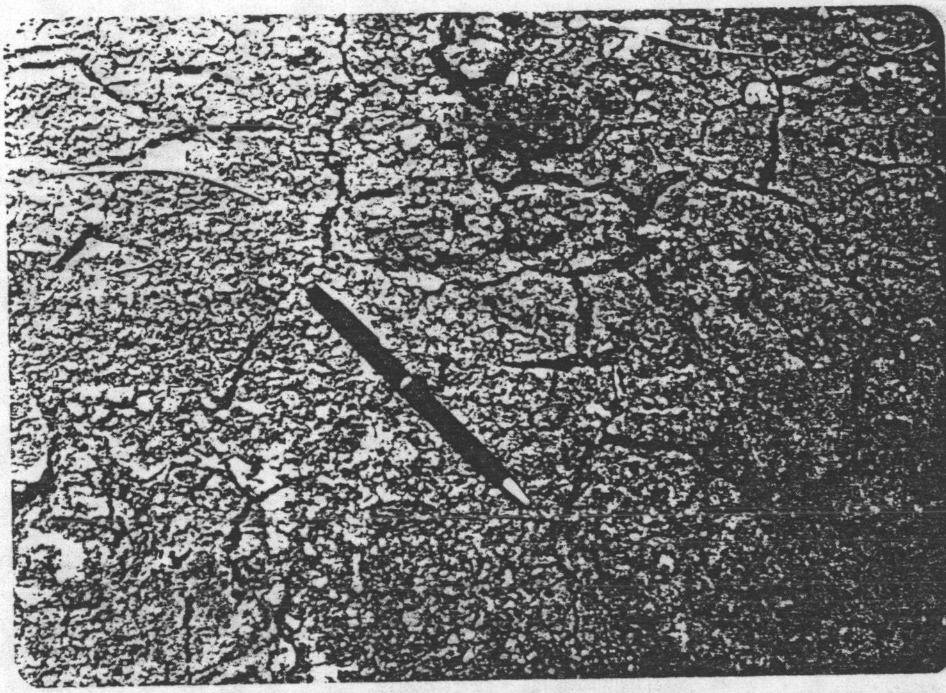


PLATE 2-1 VERTISOL SOILS

The above photograph depicts the vertical cracks which can occur in the vertisol soils common throughout the NWIRP-McGregor site. As these soils dry out, which readily occurs in this portion of central Texas, they develop cracks such as those pictured above. These cracks provide ready access for pollutant migration.

the surface and the Hensel aquifer are many layers of impermeable limestone and shale.

The Edwards Limestone, which is located some 100 feet beneath the site, could in the future be used as a source of potable water. Contamination of this unit is possible.

All the streams which occur within the boundaries of the NWIRP-McGregor site are intermittent, these streams are dry, with many flowing only following periods of rain. Much of the discharge into these streams either percolates into the subsurface or evaporates before it leaves the site. The fact that the site's streams are intermittent is of significance in that this serves to reduce the threat of contaminated surface water migrating from the site.

In examining the individual operating areas, there were no significant findings, as far as potential contamination problems, in the following operational areas: A and C (Administration and Industrial Security), D (Machine Shop & Tool Fabrication Plant Services), H (Storage Magazines), R (Environmental & Static Testing), and T (Crating & Shipping). In the other operational areas there were significant findings. These include the following areas: E (Receiving, Warehousing & Vehicle Maintenance), F (Engineering Laboratories and Pilot Production), G (Tooling & Equipment Storage), L (Static Testing), M (Manufacturing), and S (Explosives Disposal). Each of the operating areas where there were significant findings is discussed in the following pages.

2.1 AREA E (RECEIVING, WAREHOUSING, & VEHICLE MAINTENANCE)

Located just southeast of the boundary of Area E is a landfill and open dump. During EEI's investigation of this site, only non-hazardous material composed of building demolition, pallets, empty drums, and drums of blasting sand was uncovered. No hazardous materials were discovered, nor were there any indications that hazardous materials had been disposed of at this site. This landfill and open dump covers approximately 1-1/2 acres of disturbed land. The area surrounding the landfill is nearly level with a slope of about one percent. There is no defined surface drainage into or out of the landfill, and no evidence of material transport. The existing climatic conditions make leachate production minimal.

The site configuration at the area most concentrated with wastes could possibly generate leachate. The soil has been excavated here and a depressed area created where water could pool. The excavated soil has been used to create a partial berm around this portion of the landfill. A photo of the area is presented in Plate 2-2.

PLATE 2-2 AREA E DUMP

Photograph of the dumping ground located just southeast of Area E. As is evidenced by the photograph, the materials disposed of here include drums, pallets, and building demolition type materials. From an inspection of the area, it was found that most of the drums were either empty or contained blasting sand. Blasting sand was also scattered about on the ground and can be seen in some portions of the photograph.

2.2 AREA F (ENGINEERING LABORATORIES & PILOT PRODUCTION)

Located within Area F are two sets of settling ponds which date back to 1953. There are three ponds (West Settling Ponds) which are connected in a series along the western boundary of the area, and another two ponds (East Settling Ponds) in the northeastern section of the area. These two sets of settling ponds will be discussed separately.

2.2.1 West Settling Ponds

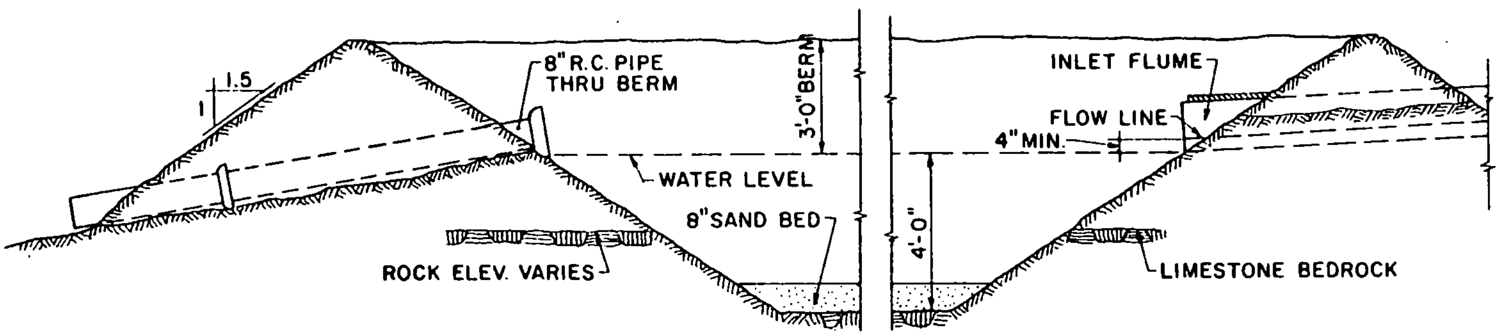
Discharge water from the All-Up-Round (AUR) missle assembly and TATB production is fed to these three ponds through a series of covered concrete flumes. Wastewater from the southern and western portion of the area discharges into these ponds. The wastes which go into these three ponds include Triaminotrinitrobenzene (TATB), Trichlorotrinitrobenzene (TCTNB), Trichlorobenzene (TCB), toluene, ammonium nitrate, and ammonium perchlorate. Sulfuric and nitric acid are also discharged into those settling ponds, as well as caustic to control the pH. The TATB, TCTNB, and TCB are soluble in water in the ppb range.

The presence of toluene and the chlorinated benzenes is of particular importance. For the protection of human health from the toxic effects of toluene, the ambient water criterion is 14.3 mg/l. For the chlorinated benzenes, the estimated level for a 10^{-5} incremental increase of cancer risk in humans (one additional case of cancer per 100,000 people) is 7.2 ng/l. These levels were obtained from the Guideline Water Quality Criteria published by the EPA on November 28, 1980 (Federal Register, vol. 45, No. 21). It is very possible that these concentrations could occur in the surface water and shallow groundwater.

The construction of these ponds is very important in assessing the potential for contamination migration. As previously mentioned, these ponds date back to 1953. During construction, excavation extended into the underlying limestone bedrock. An eight-inch bed of sand was also installed in the bottom of each pond. These ponds were designed for a water depth of approximately four feet, with an additional three feet of freeboard to the top of the berm. Each of the three ponds is also equipped with an overflow pipe. Figure 2-1 shows a typical section through the settling ponds.

The fact that these ponds were excavated into the bedrock is significant. Often the upper portions of the limestone are fractured (Appendix A). It is possible that there could be leakage from the ponds through these fractures in the limestone. The eight-inch bed of sand in the bottom of these ponds would not prevent leakage into the fractured limestone.

The clay soils with which the berms are constructed serve as an effective barrier to leachate migration. However, it is possible that the permeability of these clays has been increased by the caustic solution added to control the pH. This has been shown to occur in previous studies (Morrison, 1981). If these soils are allowed to dry, they would develop shrinkage cracks, greatly increasing their permeability.



EEI

1730

AREA F

TYPICAL SECTION THRU SETTLING PONDS

FIGURE 2-1

These settling ponds are adjacent to a well-defined tributary of Harris Creek. This tributary occurs just to the west of these ponds (Figure 6-6). The discharge from these ponds flows into a stock pond to the northeast. From this pond, drainage continues into Harris Creek and eventually into the South Bosque River.

There is a hydraulic head differential between the settling ponds and the creek, with the settling ponds being approximately ten feet higher than the creek. Thus, a hydraulic gradient is created in which the potential water flow is from the settling ponds into the tributary.

2.2.2 East Settling Ponds

These two ponds are presently dry, and there has reportedly been no discharge since the early 1970's. These ponds also receive wastes through a system of covered concrete flumes which serve the northeastern buildings of Area F. Presently, these ponds get only washdown operations. Ammonium perchlorate and ammonium nitrate residues are likely in these ponds. In the past, these ponds received wastes from ignitor and pyrotechnics operations. It is possible that trace amounts of metals and explosives were discharged into the ponds.

Discharge from these ponds is into a drainage ditch which leads into a tributary of Harris Creek (Figure 5-7). This is the same tributary of Harris Creek which receives discharge from the west settling ponds. These east settling ponds are similar to the west settling ponds in that the ponds are located higher than the drainage ditch. However, in the east ponds, the horizontal hydraulic gradient is less than that found at the west settling ponds, so the migration would be slower. These settling ponds do not represent as significant a threat to surface and groundwater contamination as do the west settling ponds.

In examining past records, it was discovered that tetryl was used in Area F during the Bluebonnet Ordnance Plant period of WWII. The tetryl was used in boosters as a detonator. It is not known how the tetryl was disposed of, but it could be a potential contamination threat. It was also discovered that, during at least a portion of the WWII operations, a pond was located where the east ponds are now. Plate 2-3 depicts Area F.

2.3 AREA G (TOOLING & EQUIPMENT STORAGE)

Located in Area G is a pesticide dump site which has areas totally void of any vegetation. This pesticide dump site supposedly dates back to the 1948-1952 period when Area G was operated by the Geigy Company as a pesticide formulation plant. The chemicals used in Area G during the Geigy period of operation included DDT, toxophene, parathion, sulfur, aldrin-dieldrin, chlordane-heptachlor, BHC-Lindane, and endrin. This list of chemicals was obtained from the "Soils Contamination Investigation" undertaken in 1979 by SOUTHNAVFACENGCOM, and from conversations with a representative of Geigy Company's (now CIBA-Geigy) Environmental Control office in Ardsley, New York.

PLATE 2-3 AREA F

Photograph of Area F depicting the east and west settling ponds. The east ponds are shown to be dry, and there has reportedly been no discharge from these ponds since the early 1970s. The west ponds, on the other hand, are in use as evidenced by the above photograph. Also shown is the drainageway which receives the effluent from the west ponds. The drainageway is located just west of the ponds and flows into the stock pond shown north of Area F. This stock pond also receives runoff from the pesticide dump site in Area G which is discussed latter.

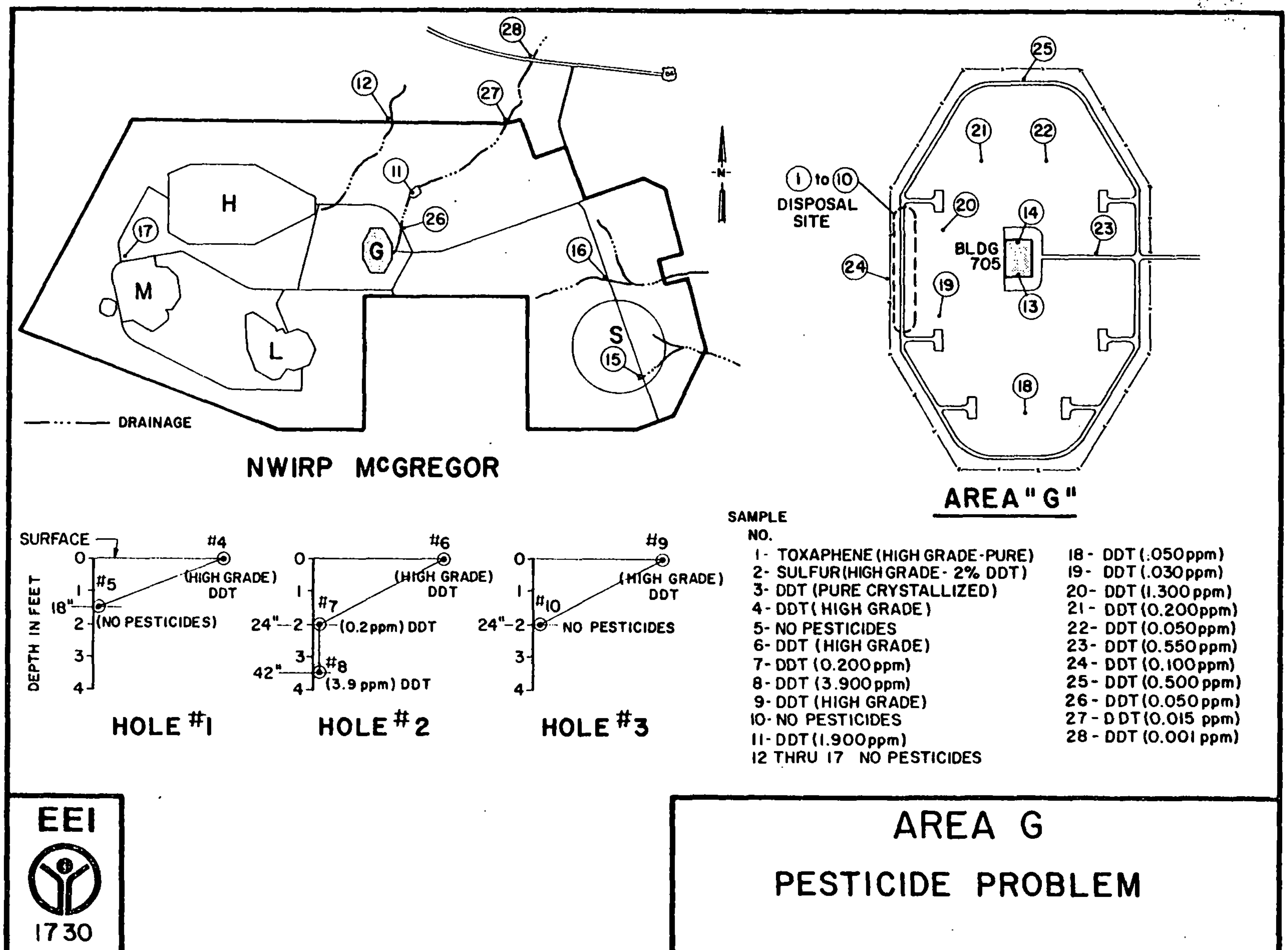
The areas which are void of vegetation are located between the perimeter road and boundary fence along the western portion of Area G (see Figure 2-2 for the location of the pesticide spill site). The largest unvegetated spot covers an area of approximately 20 feet by 100 feet. Also located between the perimeter road and boundary fence are other smaller unvegetated spots. These occur in an area which is approximately 60 feet wide by 600 feet long (see Plate 2-4). While these unvegetated spots pinpoint the location of the most seriously and highly contaminated areas, this does not mean that the surrounding areas were not also subjected to chemical dumping. The actual extent of the pesticide dumping is unknown, but in all likelihood dumping occurred on both sides of the perimeter road. The "Soils Contamination Investigation" also shows the pesticide spill area being located on both sides of the perimeter road.

The pesticide dump site is located within the Harris Creek watershed. Surface drainage flows in a general northeastward direction from the pesticide dump site. The actual surface drainage at the pesticide dump site is poorly defined. The perimeter road is slightly raised, but runoff from the pesticide site probably crosses the road. There was no indication of erosion, but the slope is generally too low for noticeable erosion to occur. Surface drainage from the pesticide dump site flows into Harris Creek (see Figure 5-7 for the general surface drainage in the area of the pesticide dump site).

In the "Soil Contamination Investigation" undertaken in 1979 by SOUTHNAVFACENGCOM, numerous soil and sediment samples were taken and analyzed for pesticides. These samples were taken within the area of the pesticide spill, within the drainage area of the pesticide dump site, and outside the drainage area of the pesticide dump site. These consisted mostly of surface samples and shallow soil samples taken at three inches below grade. However, there was a sample taken at a depth of 18 inches, two at a depth of 24 inches, and one at a depth of 42 inches. There were also sediment samples taken from drainageways and ponds.

The results of this analysis showed that other than one isolated surface deposit of pure grade toxophene, the only contaminant still present in the samples was DDT. This is not surprising since DDT is very persistant in the environment. In the unvegetated areas high grade DDT was found and, in one sample, pure crystallized DDT was present. Figure 2-2 contains a map showing the location of the soil samples and the levels of DDT that were found in the samples.

From the limited number of deep soil samples taken in this investigation, it is difficult to conclude whether there is any downward migration of the DDT in the soil. There were three holes dug in order to obtain the deeper soil samples. In two of these holes the surface sample indicated DDT, but the samples taken at 18 inches in one hole and 24 inches in the other indicated no DDT. In the other hole, DDT was found at 3.9 ppm at a depth of 42 inches. However, this finding is very questionable since a sample taken from the same hole at a depth of 24 inches indicated only 0.2 ppm DDT. While it appears that there may be no downward movement of the DDT, more thorough deep soil testing is needed to verify this.



DRAINAGE
NWIRP McGREGOR
H
M
L
G
S
N
1 to 10 DISPOSAL SITE
BLDG 705
AREA "G"
SURFACE
DEPTH IN FEET
#4 (HIGH GRADE) DDT
#5 18" (NO PESTICIDES)
HOLE #1
#6 (HIGH GRADE) DDT
#7 24" (0.2 ppm) DDT
#8 42" (3.9 ppm) DDT
HOLE #2
#9 (HIGH GRADE) DDT
#10 24" NO PESTICIDES
HOLE #3
SAMPLE NO.
1- TOXAPHENE (HIGH GRADE-PURE)
2- SULFUR (HIGH GRADE- 2% DDT)
3- DDT (PURE CRYSTALLIZED)
4- DDT (HIGH GRADE)
5- NO PESTICIDES
6- DDT (HIGH GRADE)
7- DDT (0.200 ppm)
8- DDT (3.900 ppm)
9- DDT (HIGH GRADE)
10- NO PESTICIDES
11- DDT (1.900 ppm)
12 THRU 17 NO PESTICIDES
18- DDT (.050 ppm)
19- DDT (.030 ppm)
20- DDT (1.300 ppm)
21- DDT (0.200 ppm)
22- DDT (0.050 ppm)
23- DDT (0.550 ppm)
24- DDT (0.100 ppm)
25- DDT (0.500 ppm)
26- DDT (0.050 ppm)
27- DDT (0.015 ppm)
28- DDT (0.001 ppm)
EEI
1730
AREA G
PESTICIDE PROBLEM

FIGURE 2-2

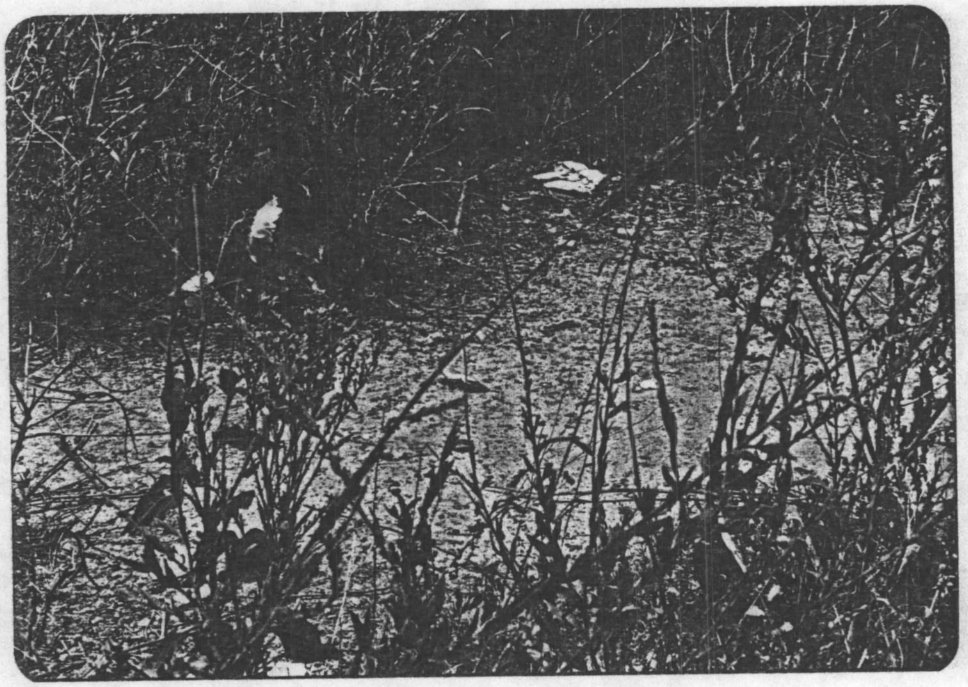


PLATE 2-4 PESTICIDE DUMP

Photograph depicting a portion of the pesticide dump in Area G. This is an illustration of one of the numerous unvegetated sites which occur throughout the dump area. These unvegetated sites signify areas of high level DDT contamination.

This analysis does, however, indicate that the DDT is migrating horizontally and is spreading into the Harris Creek watershed. These surface samples range from pure DDT in the unvegetated areas, to 0.001 ppm in the sediment of the drainage ditch which passes under Highway 84 approximately one-half mile northeast of the NWIRP-McGregor site (see Figure 2-2 for a listing of the DDT levels in the other surface samples and for their location). Of particular significance is the 1.90 ug/g of DDT in the sediment of the stock pond which is located approximately 3/4 of a mile to the northeast of Area G.

The levels of DDT found in these samples is of significance, both in terms of human health and freshwater aquatic life. For DDT and its metabolites, the criterion to protect freshwater aquatic life is <u>0.0010 ug/l</u> as a 24-hour average and the concentration should not exceed <u>1.1 ug/l</u> at any time. In terms of human health, the level of DDT for a 10^{-5} cancer risk (one additional case of cancer per 100,000 population) is set at <u>.24 ng/l</u>. These levels are from the Guideline Water Quality Criteria published by the EPA on November 28, 1980 (Federal Register, Vol. 45, No. 231). While these criteria are based on levels of DDT in water, the fact that the DDT is present in the soil and sediment samples in concentrations far in excess of these recommended guidelines is reason to be concerned. Because of the high concentrations found in the sediments, it seems possible that the water quality standards could be exceeded in the drainage area of the pesticide dump site and, thus, represents a significant problem, as a threat to the protection of freshwater aquatic life.

It is possible that not all of the DDT found in the samples comes from the pesticide dump area. Some of the DDT could be the result of agricultural pesticide applications over the years. However, since the soil samples taken outside of the pesticide dump drainage area had no detectable level of DDT, an agricultural source does not seem likely.

2.4 AREAS J & K

These operating areas are no longer within the boundaries of the NWIRP-McGregor site, but during WWII they were bomb loading lines. TNT was used as the explosive in most of the bombs produced at the old Bluebonnet Ordnance Plant. Each of the bomb loading lines had washout pits where most of the suspended TNT was removed from the bomb washout wastewater. Some TNT was in solution in this wastewater. The method used to dispose of this TNT contaminated wastewater was to impound the water in long ditches and let it infiltrate into the soil. Shallow groundwater contamination was very possible. Whether this contamination still persists is unknown, but it is possible that this contamination could migrate to the South Bosque River.

2.5 AREA L (STATIC TESTING)

Located in the southwestern portion of Area L is a waste asbestos disposal site. This disposal site dates back to the period following WWII and up until the early 1950's when Area L was operated by the Union Asbestos Company. The asbestos pile is located west of Building L-1149, and covers an area approximately 175 feet by 300 feet. Refer to Figure 2-3 for the location and surface configuration. The asbestos pile presents no danger in terms of groundwater contamination, as the asbestos particles would be filtered out in the soil before reaching the groundwater. However, the asbestos presents a problem in terms of surface water contamination.

The asbestos disposal site is adjacent to a well-defined surface drainageway. At the base of the asbestos pile is also a culvert which receives drainage from the pile. This culvert flows into a ditch which enters a tributary of the South Bosque River. There is definite evidence of asbestos transport via the culvert and ditch toward the South Bosque River. A softball-sized piece of asbestos was found in the drainageway south of the disposal site, indicating that transport of asbestos is occuring. If the asbestos reaches the South Bosque River, it could potentially flow into Lake Waco.

The presence of asbestos in the surface water is of importance because of its proven carcinogenic nature. In terms of protecting human health, the USEPA suggests that there should be no detectable levels of asbestos in water. The levels of asbestos which may result in an incremental increase of cancer at 10^{-5}(one additional case per 100,000 population) is 300,000 fibers/l. This was obtained from the Guideline Water Quality Criteria published by EPA on November 28, 1980 (Federal Register, Vol. 45, No. 231).

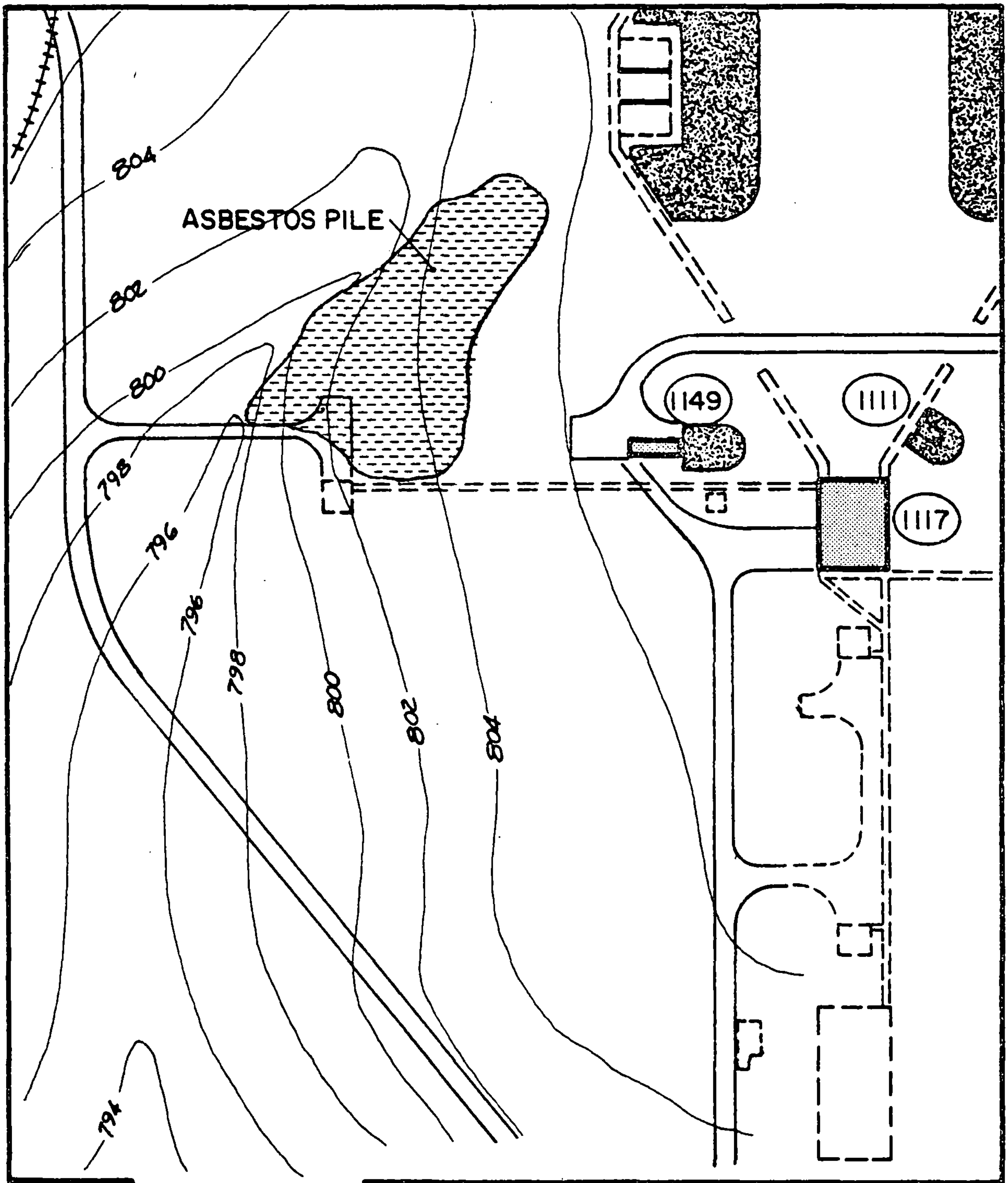
Also located in Area L, in the southeastern corner of Building L-1117, is an area which is unvegetated. This unvegetated spot covers an area which is approximately 30 feet by 30 feet. It is not known why this area is unvegetated, but during WWII, Area L was a bomb loading line. Thus, Area L had the same bomb washout pits and ditches as discussed under Areas J and K. This unvegetated spot may date back to WWII, since only static testing has occurred in Area L since the middle 1950's. Drainage from the unvegetated area enters the South Bosque River.

2.6 <u>AREA M (MANUFACTURING)</u>

Within Area M there are four sites of particular interest in terms of potential contamination. These include the interior settling basins outside Buildings M-1217 and M-1227, the north stock pond, the propellant washout pond outside Building M-1219, and the Imhoff tank and stabilization ponds.

2.6.1 <u>Interior Settling Basins</u>

Outside Buildings M-1217 and M-1227 are small interior settling basins. These basins receive floor drain wash water, which could contain waste propellants. However, care is taken to make certain that any scrap propellants are collected for disposal at the burning ground. These settling basins are not ponded very frequently. Any discharge from these settling basins enters via a ditch into a tributary of Station Creek. There is a potential for contamination at these settling basins; however,



AREA L
ASBESTOS PROBLEM

FIGURE 2-3

it should not represent a significant problem.

2.6.2 North Stock Pond

This pond is located approximately 1/5 of a mile north of Building M-1205 where the conversion coating operation occurs. This pond receives the wastes from this conversion coating operation. This waste could include Trichloroethylene (TCE) and chromium.

The TCE is used in a vapor degreaser. This is emptied about once a year, with the wastes going to a hazardous waste disposal site. However, there may be some very small amount of carryover of the TCE from the vapor degreaser which could be discharged into the pond. The possible presence of TCE is of importance because of its carcinogenic nature. The levels of TCE which result in an incremental increase of cancer risk at 10^{-5} (one additional case of cancer per 100,000 population) is 26 ug/l. This level was obtained from the Guideline Water Quality Criteria published by EPA on November 28, 1980 (Federal Register, Vol.45, No.231).

There is also the possibility of chromium being present in the wastewater which enters this pond, since it is used in the conversion coating process. For the protection of human health from the toxic effects of chromium VI, the ambient water criterion reccommended by the EPA in the Guideline Water Quality Criteria is 50 ug/l (Federal Register, Vol.45, No.231).

This pond is part of a well-defined surface drainage system. Drainage from the pond enters into a tributary of Station Creek.

2.6.3 Propellant Washout Pond

This pond is located outside of Building M-1219 and is used for propellant washout. There is a possibility of ammonium perchlorate contamination in this pond. The pond is approximately 10 feet by 30 feet, and its depth is less than 2 feet. Methylene chloride is sometimes used to soften rubber in the motor washout operation.

Any overflow from this washout pond has ready access to a tributary of Station Creek via a drainage ditch. This washout pond is higher than the water table and appears to contain water the majority of the time. The possibility for some recharge to the groundwater exists. However, these wastes are not highly toxic and don't represent a serious problem.

2.6.4 Imhoff Tank & Stabilization Ponds

There is no evidence that hazardous wastes are or have been discharged into the Imhoff system which would present a contamination threat.

However, Area M was a bomb loading line during WWII and, thus, there is a possibility that bomb washout pits and leaching trenches are present in this area.

2.7 AREA S (EXPLOSIVES DISPOSAL)

Materials disposed of at the burning grounds include waste ammonium perchlorate and ammonium nitrate propellants, propellant-contaminated wastes such as gloves and rags, and waste toluene bottoms. The materials disposed of at the burning grounds have contaminants which are readily destroyed, and the residue left is not hazardous. The waste toluene is burned in a steel container so that none is absorbed into the soil.

Burning takes place in the center of Area S (see Plate 2-5). A rectangular berm has been constructed around this area (Figure 6-19). This berm is 2 to 3 feet high and is reportedly constructed of low permeability clays. It is possible that this berm could cause water to pond within the area where burning takes place, but toxic materials are not stored in this area and the residue left from burning is not hazardous. There is evidence of shrapnel throughout the area between the berm and fence, but this material is inert.

The burning grounds are located in an area with no developed surface drainage system. The area is nearly level, with slopes of only one percent. There is no visible evidence of contaminant migration or erosion from the burning area. Surface drainage from the burning area ultimately ends up in the South Bosque River which flows into Lake Waco. There are two ponds located up gradient from the area and another located down gradient (Figure 6-19).

It was also discovered that there was a landfill located in the southeastern portion of the Explosives Disposal Area. This landfill reportedly received sludge from a zinc-phosphate operation which is no longer in operation at the NWIRP-McGregor site. This landfill also reportedly received a wide assortment of other wastes. There is no defined surface drainage in the area of the landfill. Leachate production at the site would be minimal due to the climatic characteristics and soils of the area.

2.8 GENERAL SIGNIFICANT FINDINGS

Most common solvents are used in small quantities throughout the NWIRP-McGregor site. Small spills of these solvents could lead to groundwater contamination. Simply because of their widespread use, the potential is present at the NWIRP- McGregor site for solvent spills to occur, though no reports of spills were encountered during EEI's investigation. However, because this potential is present, any groundwater samples collected at the site should, therefore, be screened for volatiles.

One off-site area where wastes from the site were reportedly disposed of was discovered during interviews with area residents and site personnel. This was an old landfill and open burning area located at the

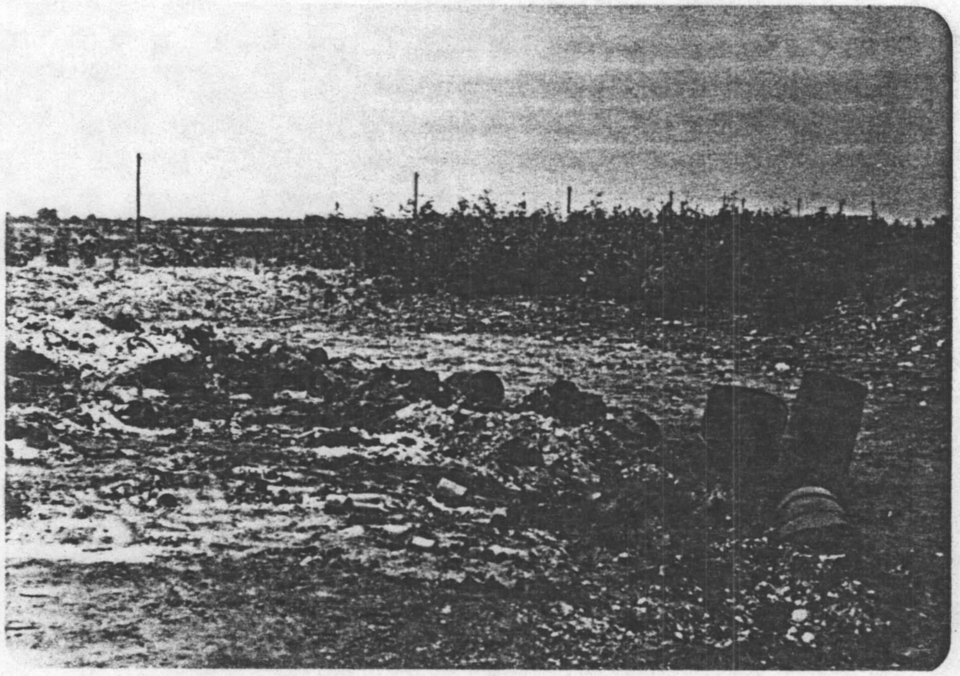


PLATE 2-5 BURNING GROUNDS

This is a photograph of the central portion of Area S where the actual burning of waste propellants, propellant-contaminated materials, and toluene bottoms occurs. Burned-out drums and other metal canisters are scattered throughout the burning area, as is evidenced by the photograph. Also depicted in this photograph is the berm which surrounds the burning area (located about two-thirds of the way up the photograph). The berm prevents surface runoff from leaving the burning area.

Texas A&M Experimental Station. During the cleanup operations following the end of WWII, the Army reportedly utilized this site for the disposal of ordnance and non-ordnance materials. These ordnance materials may have included unspent shells as explosions were reported at the site during burning, although this could not be documented. Thus, there is a potential for contamination at this site. The potential for contamination migration is also high at this site as a result of its proximity to the South Bosque River.

3.0 CONCLUSIONS

Contained within this chapter are the significant conclusions reached regarding contamination and migration potential for the NWIRP-McGregor site.

3.1 CLIMATE

The climatic characteristics of the site are not conducive to leachate production at a properly designed landfill. The intense rainfall episodes, which are common to the area, create a potential erosion problem and create the potential for surface migration of contaminants.

3.2 SOILS

The soils throughout the site are subject to developing vertical cracks when dry. These cracks are a potential threat which could lead to shallow groundwater contamination. When wet these soils are highly impermeable.

3.3 GROUNDWATER

The potential for shallow groundwater contamination does exist throughout the site. However, the deep Hensel aquifer, which is the principal water supply aquifer for the area, is not in danger of contamination.

The Edwards Limestone, due to the continual depletion of the Hensel aquifer, may out of necessity be utilized as a source of water for human consumption. The Edwards Limestone occurs some 100 to 130 feet beneath the surface, and could potentially become contaminated.

Off-site and on-site movement of shallow groundwater is not significant at the NWIRP-McGregor site, because of the topography of the site.

3.4 SURFACE WATER

Runoff from every operational area of the site except Area M (Manufacturing) ends up in Lake Waco, which is a major water supply reservoir for the city of Waco. Contaminants originating from the NWIRP-McGregor site could conceivably contaminate this water supply.

3.5 MIGRATION POTENTIAL

Areas which were contaminated, or where contamination is a possibility, were identified at the NWIRP-McGregor site. It is possible that pollutants could be migrating from these areas off-site. The most serious pollutant migration threat is from surface water leaving the site.

There is no significant danger of pollutants migrating onto the NWIRP-McGregor site, either in surface water or groundwater.

3.6 AREA E - LANDFILL

There is no significant surface or groundwater contamination threat from this landfill.

3.7 AREA F

3.7.1 West Ponds

There is a potential for surface water and shallow groundwater contamination from these ponds. The main contaminant threats are from toluene and chlorinated benzenes. The chlorinated benzenes represent a significant contamination threat, while the toluene represents a potential threat. Groundwater contamination potential is limited to the shallow aquifer.

3.7.2 East Ponds

The present operations which drain into these ponds pose no contamination problems to surface water or groundwater.

In Area F as a whole, there is a potential for groundwater contamination from tetryl which dates back to WWII operations in the area. Past operations could also have increased the level of nitrates in the groundwater.

3.8 AREA G

The pesticide dump is a continuing threat to surface water contamination, and the potential exists for shallow groundwater contamination, although additional sampling is needed to verify this.

3.9 AREAS J&K (OLD BOMB LOADING LINES)

The present operations in these areas present little likelihood of contamination. However, the bomb loading operations which occured in these areas during WWII could potentially have contaminated the shallow groundwater with TNT.

3.10 AREA L

The asbestos pile represents an immediate and on-going threat to surface water contamination.

TNT contamination, dating back to the area's bomb load-line days, is also possible from the TNT washout pits and trenches.

3.11 AREA M

The conversion coating operation has limited potential for surface water contamination.

The contamination potential from post WWII operations is insignificant in the interior settling basins.

The propellant washout pond could add nitrates to the surface water and groundwater, but this is not significant in light of fertilization practices in the area and the small size of the pond.

In Area M as a whole, there is a potential for TNT contamination. This stems from the fact that the area was a bomb loading line in WWII and likely had TNT washout pits and trenches.

3.12 AREA S

The burning area poses no threat to groundwater or surface water contamination.

3.13 TEXAS A&M EXPERIMENTAL STATION

Materials disposed of at this site date back solely to Army ownership. The Air Force and Navy did not dispose of any materials at the site. The Army has not conducted an Initial Assessment Study or a Confirmation Study at the Experimental Station, and they do not presently have any plans to do so. Any possible contamination from this site would migrate into the South Bosque River, not on-site.

4.0 RECOMMENDATIONS

Based on an analysis of the significant findings, EEI believes that certain areas at NWIRP-McGregor have a significant contamination potential, and that these areas pose a threat to human health and/or the environment (Figure 4-1). Therefore, EEI recommends that a confirmation study be initiated at NWIRP-McGregor. The areas which EEI believes warrant further investigation are listed below. These areas, and EEI's specific recommendations for further actions at these areas are as follows:

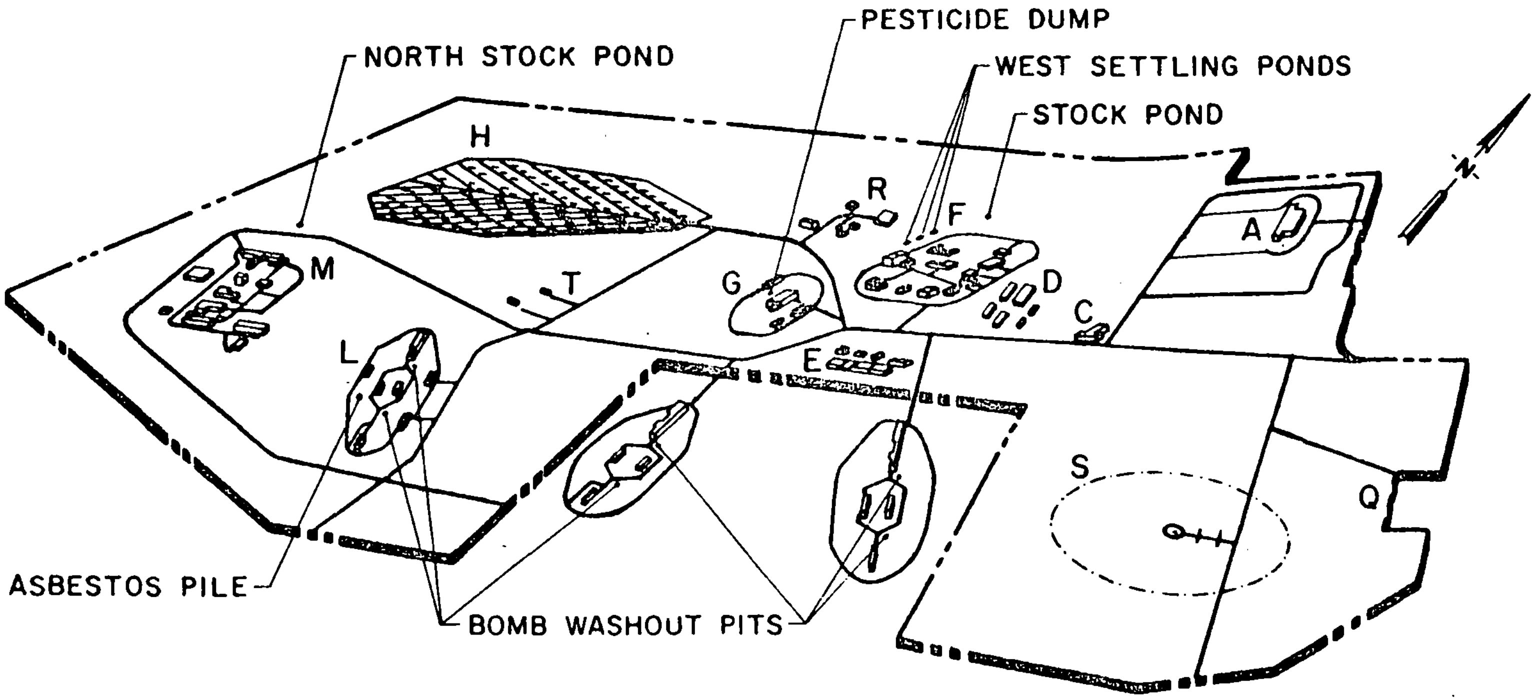
Area F:	West Ponds
	Stock Pond
Area G:	Pesticide Dump
Area L:	Asbestos Dump
	WWII Washout Pits and Leaching Trenches
Area M:	North Stock Pond
	WWII Washout Pits and Leaching Trenches

4.1 AREA F (ENGINEERING LABORATORIES AND PILOT PRODUCTION)

The wastewater discharged to the west ponds from the present production of TATB probably contains trace amounts (ppm) of TATB, chlorinated benzenes (e.g., TCTNB, and TCB), and toluene. Since concentrations as low as 7 parts per trillion (ppt, or ng/l) in drinking water may increase the risk of cancer in humans, the suspected presence of these compounds in the wastewater discharged to the west ponds is cause for concern.

The construction details of the ponds, the soils and bedrock in the vicinity of the ponds, and the hydraulics of the ponds, suggest that some leaching from the bottoms of the ponds into the shallow groundwater system may be occurring. The effluent from these ponds contains ppm levels of Chemical Oxygen Demand (COD). This may be caused by toluene and/or TATB and the chlorinated benzenes. Therefore, the effluent from these ponds may also be contributing significant levels of contaminants to surface water.

Based on the above, EEI recommends that the following sampling and analysis program be implemented.



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NWIRP - McGREGOR
POTENTIAL CONTAMINATION
SITES

FIGURE 4-1

4.1.1 Groundwater Monitoring

Figure 4-2 shows six locations where EEI recommends that monitoring wells be emplaced. The wells should be relatively shallow (20 to 30 feet) and screened to intersect the water table. The southern-most well should be upgradient, and used as a background well. The wells shown on the west sides of ponds 1 and 3 are positioned to intersect subsurface flow from the ponds toward the ditch. The well to the west of the ditch is positioned to attempt to determine the western extent of any shallow groundwater contamination. The well northeast of the stock pond will detect the presence of groundwater contamination emanating from that pond. The sixth well is located to attempt to detect any northerly migration of contaminants from the ponds via the subsurface.

4.1.2 Surface Water

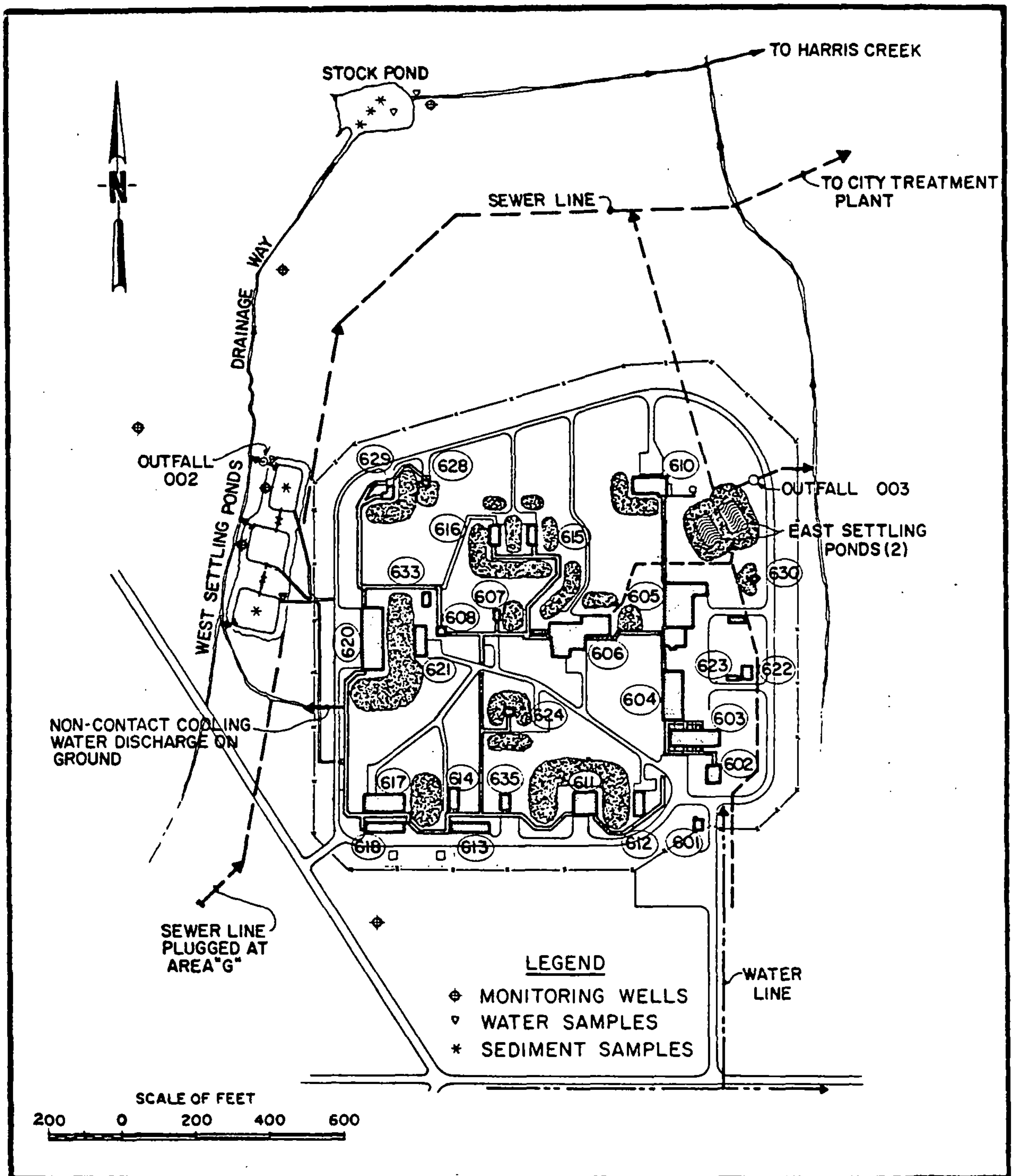
Because the levels of these organic contaminants in the wastewater have not been measured, EEI recommends sampling the influent to the ponds, the effluent, and the water in the stock pond (see Figure 4-2). The influent/effluent sampling will indicate the treatment effectiveness of the ponds. The stock pond should also be sampled to determine the extent of contaminant transport in the surface water system. A sample of the discharge from the stock pond (intermittent) should also be collected.

4.1.3 Sediment

The sediment in the ponds probably contains relatively high concentrations of organic contaminants. The sediment in the stock pond has been shown to contain ppm levels of DDT (probably originating from the pesticide dump in Area G), and may contain some of the organic contaminants from Area F. Due to the hydraulics of these four ponds, contaminants in the sediment, if present, would act as a potential continued source of groundwater contamination, even if the contaminants in the pond water were removed. Therefore, EEI recommends that the sediment in these ponds be sampled.

4.1.4 World War II Operations

During WWII operations, tetryl was handled and possibly manufactured in what is now known as Area F. If tetryl was manufactured in this area, a contaminated wastewater was probably generated. No record of the disposition of this wastewater was obtained during the record search. If it was disposed of in a manner similar to the disposal of TNT contaminated wastewater (percolation/evaporation trenches), the groundwater in Area F may be contaminated with tetryl. Since all of the existing ponds were constructed after the end of WWII, these ponds could not have been used and would, therefore, not be contaminated with tetryl. Surface runoff and shallow groundwater in the immediate vicinity of the ponds flows to the north and west toward a drainageway. The recommended location of the monitoring wells shown in Figure 4-2 may intersect the hypothetical tetryl contaminant plume. Samples from these wells should, therefore, be analyzed for the presence of tetryl. Table 4-1 summarizes the sampling and



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AREA F

RECOMMENDED SAMPLING SITES

FIGURE 4-2

TABLE 4-1

AREA F SAMPLING

		ANALYZE FOR					
	Number of Samples	Toluene	Chlorinated Benzenes	TATB	Tetryl	Volatile Organic Analysis	DDT
Monitoring Wells	6	X	X	X	X	X	X
Stock Pond Sediment	3	X	X	X			X
West Ponds Sediment	2	X	X	X			
West Ponds Influent	1	X	X	X			
West Ponds Effluent	1	X	X	X			
Stock Pond Effluent	1	X	X	X			X

analysis program which EEI recommends in relation to Area F.

4.2 AREA G (TOOLING AND EQUIPMENT STORAGE)

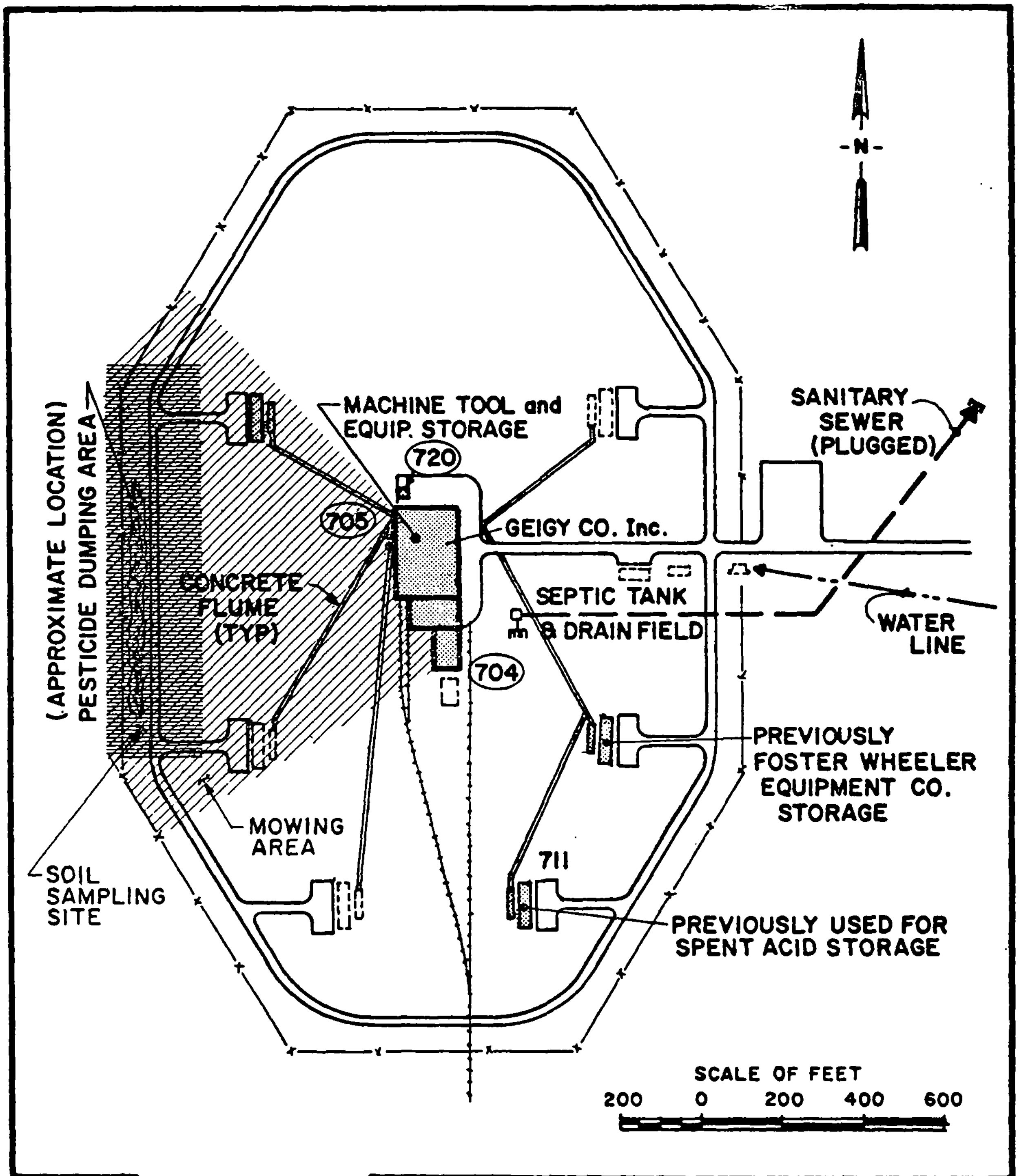
Prior to the reacquisition of Area G by the Air Force in 1952, or possibly during the initial rehabilitation efforts by the Air Force prior to the start-up of operations by Phillips Petroleum, waste pesticides were apparently dumped on the surface of the ground in the western portion of Area G. In 1978, a preliminary sampling and analysis program was conducted regarding the pesticide dump in Area G. This study concluded that there was substantial surface contamination with DDT, and that there was some transport of DDT including contamination of the sediment in the stock pond north of Area F. The study was inconclusive regarding the downward leaching of the DDT through the soils in the vicinity of the pesticide dump.

This study also indicated that dumping had occurred and contamination was present over a much larger area than was discernible during EEI's site inspection in August, 1981. This was probably due to the dense cover of Johnson grass present during August. The Johnson grass serves to hide the contaminated areas by growing over, but not in, contaminated spots. Thus, detection of contaminated areas us very difficult.

Because of the highly toxic and bioaccumulative effects of DDT, and the indication of substantial migration of the DDT through the drainageways, EEI recommends the following.

1. Determine the extent of the gross contamination in the known dumping area. In order to accomplish this, EEI recommends that a sampling grid be established in the known dump site. Figure 4-3 shows the recommended area of this grid. The grid should consist of six east-west transects, with a transect spacing of 200 feet. This will cover an area 1,000 feet long in the north-south direction. Each of the six transects should be 240 feet long, with sampling points approximately every 20 feet. This will yield thirteen sampling points for each transect, for a total of 78 sampling points. Surface grab samples should be collected to a depth of 3 to 4 inches at each sampling point. The sample should not necessarily be collected at the exact nodal points on the grid. Field judgement should be used to select samples within the general vicinity of the grid points where evidence of contamination is present. The actual sample points should be marked for future reference.

Once the analysis of the surface samples is completed, ten contaminated (500 to 5,000 ppm) sites should be selected. At each of these ten locations, samples should be collected at one foot intervals to a depth of four feet. This will determine the vertical extent of the contamination (leaching). If the results of these deeper samples indicate that deep (at least 4 feet) leaching has occurred, shallow groundwater monitoring wells should be installed. If the results of the deep sampling indicate that deep leaching has not occurred, monitoring wells would not be necessary.



EEI 1730

AREA G
RECOMMENDED SAMPLING SITE & MOWING AREA

FIGURE 4-3

2. Document the extent of migration through the drainageways This could be accomplished by collecting a series of sediment and water samples from the drainageway leading northeast from Area G. EEI recommends that six sediment samples be collected from this drainageway between the dump site and the stock pond north of Area F. Two more sediment samples should be collected from the drainageway between the stock pond and the boundary of the site. Two water samples should also be collected from this drainageway. Since flow in this drainageway is intermittent, the samples will have to be collected in association with a major rainfall event. The samples should be collected at or after the peak of the runoff has occurred - not during the early part of the storm event. One of these samples should be collected from the stream as it enters the stock pond north of Area F, and the other sample should be collected where the stream leaves the boundary of NWIRP-McGregor.

3. Attempt to locate additional areas of dumping or contamination. In order to accomplish this, EEI recommends that the Johnson grass in part of Area G be mowed and the clippings raked and removed (see Figure 4-3). Low altitude aerial photographs should then be taken of Area G in its entirety. Suspicious looking spots on the photos should be marked, and then visually inspected on the ground. Those locations where contamination or dumping is still suspected should be sampled and the locations marked for future reference.

4. General Recommendations. A variety of pesticides were handled at this facility, but the previous study detected primarily DDT contamination. Therefore, EEI recommends that all of the samples be analyzed for at least DDT. In addition to DDT, at least 20 percent of the surface grab samples should be subjected to a pesticide screen for toxaphene, parathion, aldrin-dieldrin, chlordane-heptachlor, BHC-lindane, and endrin.

Once the extent of the contamination is known, corrective measures can be initiated.

4.3 AREA L (STATIC TESTING AREA)

The waste asbestos dump located in Area L is adjacent to a well-defined drainageway. This drainageway empties into the South Bosque River which eventually empties into Lake Waco. Lake Waco is used for water supply purposes. Since the asbestos is visibly being eroded into the adjacent drainageway, and since ingestion of asbestos is suspected to have carcinogenic effects, this erosion represents a possible threat to human health.

Adverse health effects from the respiration of asbestos has been clearly demonstrated. Since excavation of the asbestos pile would likely generate asbestos dust, EEI does not recommend excavation and removal of the asbestos. However, the erosion of the asbestos into the adjacent drainageway should be halted. This could be done by covering the asbestos with earth or some other suitable covering, and rerouting the drainageway to a safe distance away from the asbestos. This effort must be carefully designed and implemented to prevent future problems from occurring and to minimize the hazard to the workers covering the asbestos.

In order to more fully document the degree of hazard posed by the erosion of the asbestos, EEI recommends that three water samples be collected. One of the samples should be collected from along the drainageway between the asbestos pile and the stock pond located to the southwest of Area L. One of the samples should be collected from the drainageway between this stock pond and the boundary of the plant. The third sample should be collected from the drainageway where it enters the South Bosque River. Since flow in this drainageway is intermittent, the samples should be collected in conjunction with a major storm event.

During WWII, bomb washout operations were conducted in the areas now known as J,K and L, and possibly M. These operations included the use of bomb washout pits (settling pits for the wash water), and long percolation/evaporation trenches for disposal of the TNT-contaminated effluent from the pits. Each load line (Areas J,K and L) had two bomb washout pits. However, it is unclear from the records whether there were one or two sets of percolation/evaporation trenches in each area, or if all of the bomb washout pit effluent from the three (or four, if Area M is included) areas went to one centralized percolation/evaporation trench.

Since this effluent was contaminated with TNT, and since the operation of these trenches was conducive to percolating the contaminated water into the ground, it appears likely that some groundwater contamination of the shallow aquifer may have occurred. Therefore, EEI recommends that an attempt be made to locate these trenches in Area L, and, once located, to install groundwater monitoring wells around them. Classified photos from WWII, available through the USEPA photo interpretation center in Vint Hill Farms, Virginia, could be used to help locate these trenches. If the groundwater has not been contaminated, no futher action may be necessary. If groundwater contamination is detected in Area L, contamination may also be present in Areas J and K, and the Navy should take appropriate measures with regard to these areas as well as in Area L.

4.4 AREA M (MANUFACTURING AREA)

The conversion coating operation conducted on the northern portion of Area M has resulted in the potential for trace amounts of chromium and trichloroethylene to be discharged into the stock pond located just north of Area M. Because of the highly toxic nature of hexavalent chromium and the carcinogenic nature of trichloroethylene, EEI recommends that a sample of the water in the stock pond be collected and analyzed for the presence of hexavalent chromium and trichloroethylene.

4.5 GENERAL RECOMMENDATIONS

4.5.1 Establish Background Groundwater Quality

Since monitoring wells are recommended for installation at NWIRP-McGregor in the shallow aquifer, and since the quality of the water in this aquifer may have been affected by agricultural activities, the background groundwater quality in this shallow aquifer may be highly variable and of generally poor quality. There are also numerous shallow, hand-dug wells located throughout the site. In order to obtain an indication of both the general background groundwater quality and the variability of the quality, EEI recommends that six of these hand- dug wells be sampled and analyzed. The analyses should include the following parameters:

GC/MS Screening	Chromium (Total)
Nitrate	Lead
TKN	Chloride
Sulfate	pH
COD	TDS

4.5.2 Signify Contaminated Areas and Disposal Areas

Mark contaminated areas and disposal areas as shown on Figure 4-1 on the activity's general development map.

*Table 4-2 provides a summary of the EEI recommendations.

TABLE 4-2

SUMMARY OF RECOMMENDATIONS

	Sampling Recommended	Analyze for	Other Recommended Action
West Ponds In Area F	Install 6 monitoring wells, sample influent and effluent of ponds, and take sediment samples from first and third pond.	Toluene, chlorinated benzenes, TATB, and wells only for Tetryl and VOA	
Stock Pond north of Area F	Sample water in stock pond and stock pond effluent, take three sediment samples in stock pond.	Toluene, chlorinated benzenes, TATB, DDT	
Pesticide Dump in Area G	Establish sampling grid at known dump site and collect 78 soil samples. Select 10 moderately contaminanted sites and sample at one foot intervals to a depth of four feet. If leaching indicated establish monitoring wells. Collect eight sediment samples from drainageway. Six between dump site and stock pond north of Area F, and two between stock pond and site boundary. Also collect two water samples from drainageway.	DDT, also at least 20% of samples should be subjected to a complete pesticide screen	Mow and remove clippings from west central portion of Area G. Take low aerial photos of all of Area G and look for additional contamination areas. Take corrective measures in areas found to be contaminated.
Asbestos Dump in Area L	Collect three water samples. One between asbestos pile and stock pond southwest of Area L, one between stock pond and plant boundary, and a third as the drainageway enters the south Bosque River	Asbestos	Cover asbestos pile and reroute drainageway to stop erosion of the asbestos
Stock Pond North of Area M	Collect water sample from stock pond .	Hexavalent chromium, and trichloroethylene	
WWII Washout Pits and Leaching Trenches	Attempt to locate leaching trenches and install monitoring wells around them.	TNT	If contamination discovered take appropriate actions in areas J and K.
Shallow Aquifer	Select six shallow hand-dug wells and sample to obtain indication of background water quality and the variability of the quality	GC/MS screening, Lead Sulfate, COD, pH, TKN, TDS, Nitrate, Chloride, Chromium (Total)	

5.0 BACKGROUND

5.1 GENERAL

The Naval Weapons Industrial Reserve Plant (NWIRP) is a government owned facility operated by Hercules Inc. The plant is situated on an irregularly shaped tract of land lying mostly in McLennan County with a small portion of the western parcel in Coryell County, Texas. The site is located approximately 20 miles southwest of Waco, as shown in Figure 5-1. The town of McGregor adjoins the facility at the northeast corner and has a population of about 4,500 persons. The plant is bordered by the St. Louis and Southwestern Railroad on the north and the Gulf, Colorado and Santa Fe to the east. The main entrance is located on Johnson Drive off U.S. 84. State Highway 317 runs along the eastern edge of the plant and FM 2671 along a major portion of the southern boundary.

This portion of Texas is primarily an agricultural area. Land bordering the east side of NWIRP is zoned as residential property; the south boundary, classified commercial, has light manufacturing operations and a university research center; and the remainder, as open farming and grazing land, is only sparsely populated.

The site presently encompasses some 9,700 acres of flatland. The tract extends approximately seven miles east and west and some three miles north and south. The layout of the various administrative, storage, manufacturing and burning areas is depicted in Figure 5-2. Facilities include more than 150 buildings containing some 846,000 sq. ft. of usable floor space, 26 miles of railroad, approximately 60 miles of macadam roads connecting the various activities on site, a central water plant and storage reservoir, numerous nonoperational industrial process facilities, and miscellaneous structures including a sewage treatment plant now operated by the city of McGregor. Electric power is provided by Texas Power and Light Co. and natural gas by the Lone Star Company.

5.2 HISTORY

The U.S. Army Ordnance Corps acquired approximately 18,000 acres of land at McGregor, Texas and established the Bluebonnet Ordnance Plant (BOP), now NWIRP, in early 1942 and operated the facility as an aircraft bomb loading plant, employing approximately 6,500 workers. The location of Bluebonnet was accomplished by the cooperative efforts of the Chambers of Commerce of Waco, McGregor and Temple, working in conjunction with the officials of the Santa Fe and St. Louis and Southwestern Railway Companies, the National Research Bureau and the War Production Board. Factors contributing to the selection of McGregor, Texas as a site for an Ordnance Plant included: no similiar establishment was located in central Texas, the ample supply of manpower in the vicinity and the proximity of railway junctions making rail routes to the north, south and east available. The name Bluebonnet was adopted as the official name of the

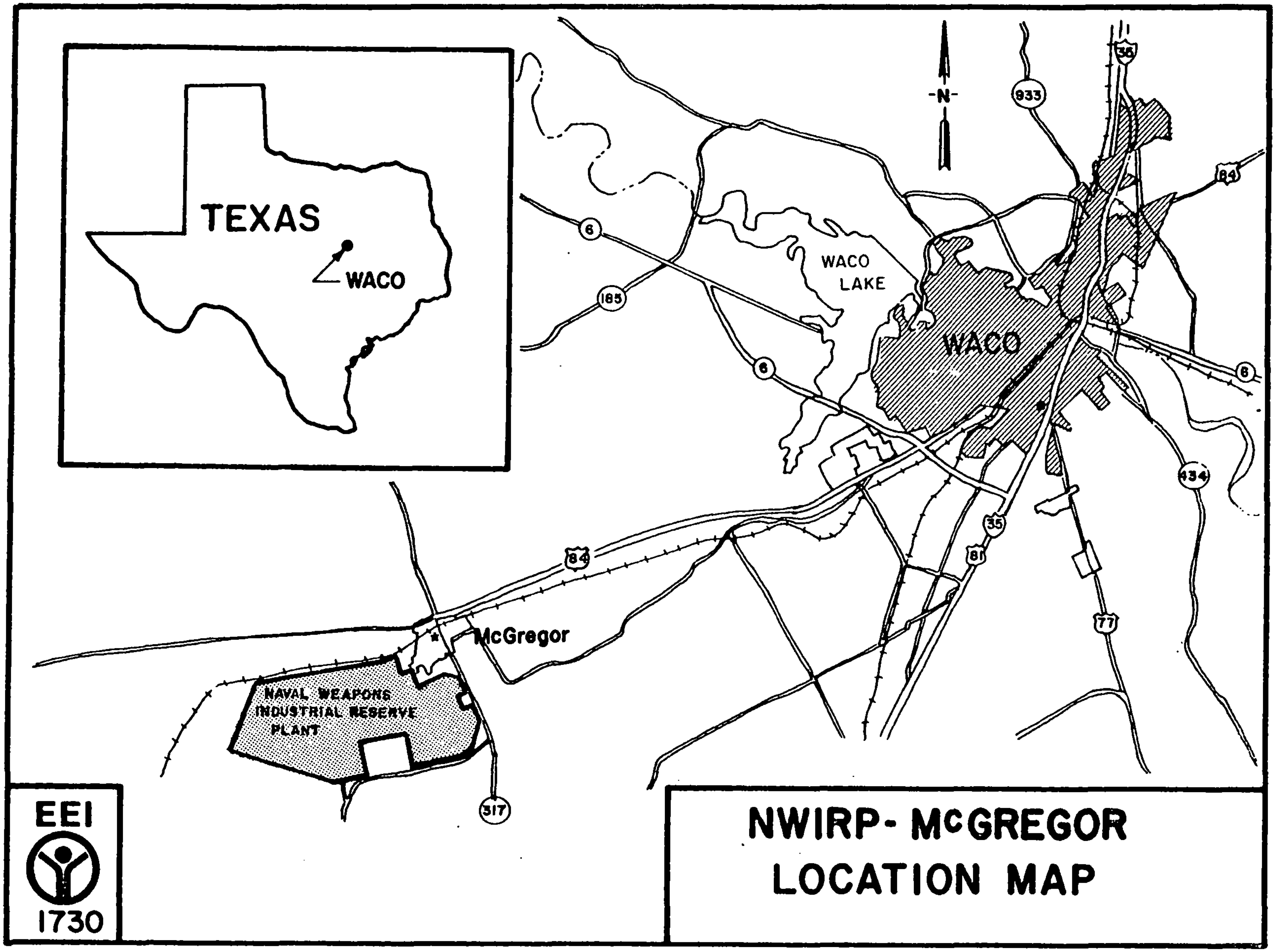
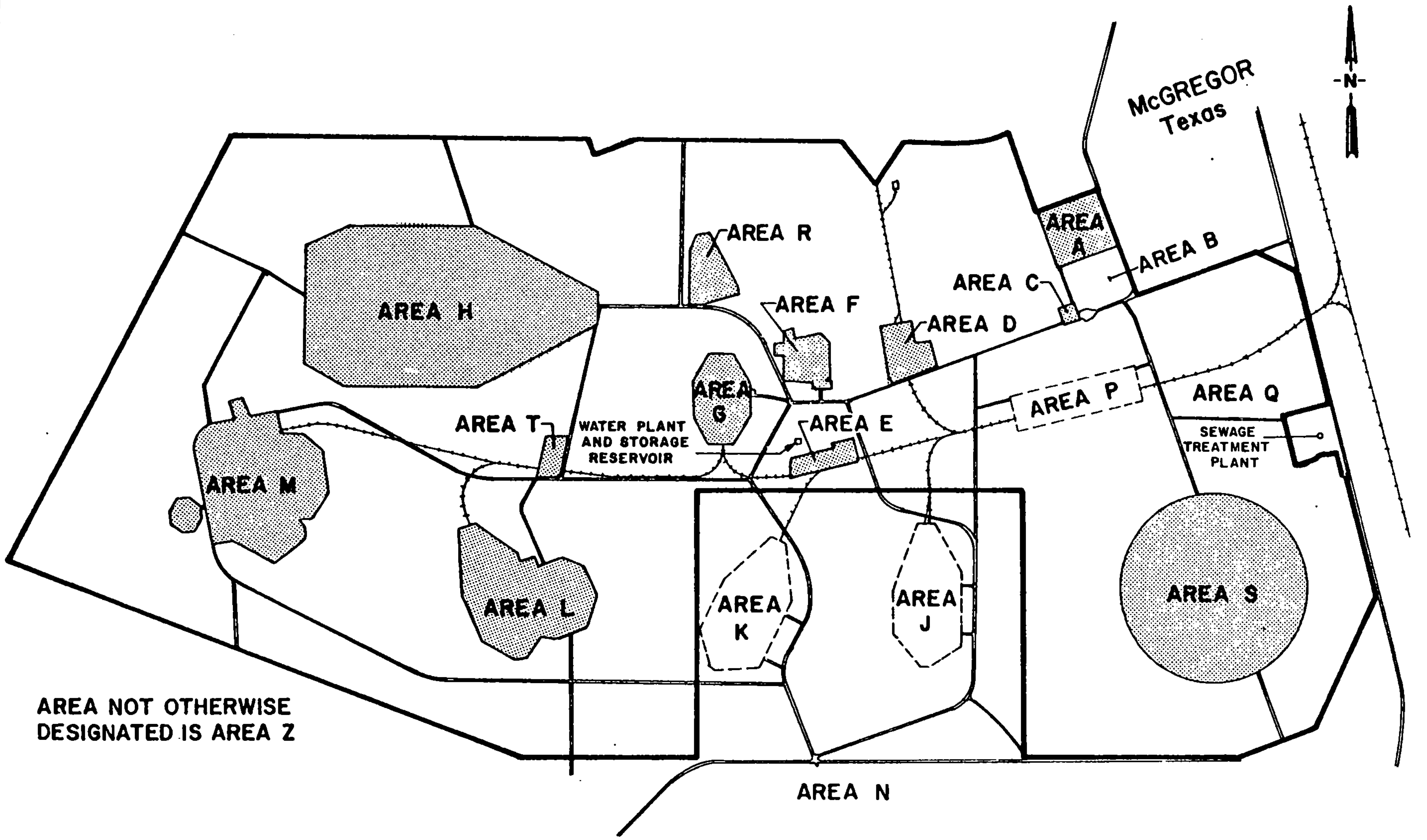

TEXAS
WACO
-N-
WACO LAKE
WACO
McGregor
NAVAL WEAPONS INDUSTRIAL RESERVE PLANT
933
35
84
6
185
6
6
434
84
35
81
77
317
EEI
1730
NWIRP- McGREGOR LOCATION MAP

FIGURE 5-1



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NWIRP- McGREGOR
SITE LOCATION PLAN

FIGURE 5-2

facility through a suggestion by Army personnel, as a name symbolic of the Texas state flower.

On February 11, 1942 Job Directive No. M1-1 was issued authorizing the construction of four Group 3 bomb load lines, each with a capacity of 3,000-100# bombs or that equivalent for a twenty four hour day and 6,000 adapter boosters and 10,000 auxiliary boosters per day. Also, an ammonium nitrate crystallizing line with ten units, each unit capable of crystallizing 33.3 tons of ammonium nitrate per day, was to be constructed. Later, Job Directive M1-2, dated April 8, 1942, reduced the proposed capacity of the plant from four to three bomb lines and from ten to six nitrate units; however, mainwater, gas, and electric facilities were to be of sufficient capacity to provide for the original proposed construction in case increased production was later required.

An expansion program started in October of 1944, added a fourth load line, now designated Area M. The line began production of 500# bombs on February 19, 1945.

The Architect-Engineer-Manager contract for facility construction, Contract #W-359-eng-4053, was awarded to the Bluebonnet Constructors on February 28, 1942, a joint venture between W.E. Callahan Construction Company of Dallas, the construction manager, and the architectural engineering firm of Howard, Needles, Tammen and Bergendoff of New York, NY. Preliminary construction work was initiated on March 5, 1942.

The constructed buildings on the reservation were roughly arranged in groups as follows:

Administration	24
Barracks & Trailer Park	33
Shop and Warehouse	5
Inert Storage	4
Booster Line	10
Ammonium Nitrate Plant	17
Bomb Load Lines (3)	75
High Explosive Storage	118
Finished Ammunition Storage	102
Miscellaneous	27
TOTAL	415

The government-owned contractor-operated (GOCO) facility was first run by the National Gypsum Company of Buffalo, New York. The contract (W-ORD-607) was awarded to the company on February 9, 1942, for operation of the plant on a cost-plus-fixed fee basis. Operations began on Bomb Load Lines 1, 2 and 3 on October 16, November 27 and December 18, 1942, respectively; and on the Bomb Booster, Oct 22, 1942. The ammonium nitrate plant started production operations on December 7, 1942.

Production schedules were not met at first due to the shortage of bomb bodies, wax for nose pads and packing boxes but by late 1943 were exceeded. The nitrate plant closed in June of 1943, and operations of

Load Lines 2 and 3 were suspended in the latter part of 1943.

However, Line 2 began production of 500 G.P. Bomb AN-M64 in September 1943, and in the following quarter, Line 1 retooled for production of 105mm Howitzer shells. Later, Line 3 reopened for production of M2 demolition blocks, and authorization was given for the manufacture of quarter (1/4) and half (1/2) pound TNT blocks from scrap for use on infiltration courses at nearby camps. Use of the ammonium nitrate crystallizing facilities for graining fertilizer grade nitrate began in October, 1943. The production of boosters was cancelled in February of 1944. Cummulative production for the plant through March 1944 was as follows:

1000-lb. S.A.P. Bombs	256,929
500-lb. G.P. Bomb AN-M64	65,079
5-lb. TNT Blocks	9,345
Fragmentary Bombs M-72	216,400
AN-M4 Cluster	368,539
105 mm. Shell	471,483
M-2 Demolition Blocks	126,089
Auxiliary Booster M-104	1,025,973
Adapter Booster M-102	412,664
Adapter Booster M-115	862,215
100-lb. G.P. Bomb	122,133
Ammonium nitrate, lbs.	16,613,590
Ammonium nitrate, tons (Fertilizer grade)	21,901

One of the important developments at the Bluebonnet Plant was a new method of rail transport of bombs, increasing the number per car from 44 to 88 by vertical crating techniques. On August 15, 1945, instructions were issued by the Commanding Officer to cease production, and immediate action was taken to put into effect post V-J Day plans.

Decontamination of production lines was completed by November 30, 1945 in accordance with FDAP Decontamination Manual Sept. 1945, and TB-eng-57. Inspections by both Ordnance representatives from OFDAP, and the U.S. Army Engineers, Galveston, Texas, of all decontamination procedures were made and approved.

No decontamination work was carried out in the High Explosive or Finished Ammunition areas due to the fact that these areas were being used for storage of approximately 40,000,000 pounds of explosives. Loading Docks 1,2 and 3 were likewise not decontaminated, because of awaited shipping orders of stored materials. Buildings which could not be adequately decontaminated were marked for destruction.

An inter-governmental agency transfer of the Bluebonnet Ordnance Plant from the War Department to the War Assets Administration was conducted on April 16, 1946, immediately following peace negotiations.

Shortly after the war, the land was sold to a number of private concerns. A major portion of the plant was conveyed to Texas A&M University for educational and research purposes. All of the parcels sold contained 20 year recapture provisions if re-establishment was required.

In 1952, the Air Force acquired approximately 11,450 acres, the major portion of the site, renaming it Air Force Plant No. 66. The new boundary lines are compared with the originals in Figure 5-3. The land within Areas J and K, totaling approximately 250 acres, remained under private ownership when the Air Force re-established the facility. The plant was reactivated for the development and production of jet assistance take-off boosters (JATO's) with Phillips Petroleum Company as the operating contractor. A considerable amount of rehabilitation and new construction was conducted at the complex during this period.

Production activities did not get under way until early 1955. JATO motors were loaded with an ammonium nitrate propellant containing a small percentage of ammonium dichromate. These motors were used as boosters on short runways and in very cold climates.

The facility was operated for the Air Force by Phillips until 1958 when North American Aviation (NAA) joined Phillips in a partnership to form Astrodyne, Incorporated. The facility subsequently entered into the high performance propellant field.

North American Aviation (NAA) bought Phillip's share in 1959 and the plant became the Solid Rocket Division of Rocketdyne. When NAA and Rockwell merged in the early 1960's, Rocketdyne became a Division of North American Rockwell Corp. and finally became known as Rockwell International Corporation's Rocketdyne Division. Under Rocketdyne the plant was modified and expanded to handle a wide variety of solid propulsion systems, exploratory, advanced and engineering development programs, as well as the production programs.

In October of 1964 the Air Force inquired as to whether the Navy would agree to accept plant cognizance since the work load was preponderantly Navy. On November 17, 1964, BUWEPS agreed to accept the facility. Following the necessary approvals and congressional concurrences, the transfer was made to the Navy.

On May 1, 1966, the land (approximately 11,450 acres), improvements, machinery and equipment of Air Force Plant No. 66 were transferred to the Department of the Navy, and became known as the Naval Industrial Reserve Ordnance Plant under the cognizance of the Naval Ordnance Systems Command. With Department of the Navy's reorganization, the plant was redesignated Naval Weapons Industrial Reserve Plant (NWIRP) under the cognizance of the Naval Air Systems Command.

Rocketdyne continued as the operator until January, 1978, when Hercules, Incorporated assumed the operating responsibilities for the facility. Hercules presently produces a number of solid propellant rocket motors including the Shrike, Sparrow, Phoenix, Sidewinder and the MK 25 JATO for the Navy. Rocket motor production operations are conducted in Areas F and M.

Since the early 1970's, approximately 1,700 acres have been disposed of. On March 27, 1972, 70.44 acres were assigned to the Department of Health, Education and Welfare (HEW) for conveyance to the McGregor Independent School District for educational use. The sewage treatment plant structure and approximately 33 acres surrounding the facility were released to the City of McGregor on June 6, 1972. This property was released with the condition that the City would continue to service NWIRP-McGregor at a non-discriminatory rate. In April 1974, seven parcels of land totaling about 1,600 acres located around the perimeter of the site were disposed of. This surplus included some 1,100 acres of land immediately surrounding Areas J and K which now forms the large privately held rectangular tract located between the static test facility (Area L) and the burning ground (Area S). This parcel excluded, of course, the two privately held portions (inside Areas J and K) totaling approximately 250 acres. The Navy acquired all of AF Plant #66. Plant AF #66 did not include Areas J and K. Presently, the NWIRP contains about 9,750 acres. The major portion of the non-operating areas, that land outside designated areas, is leased for argicultural use (approximately 8,000 acres).

The leasees of the agricultural land use the property for cattle grazing and the production of grain crops.

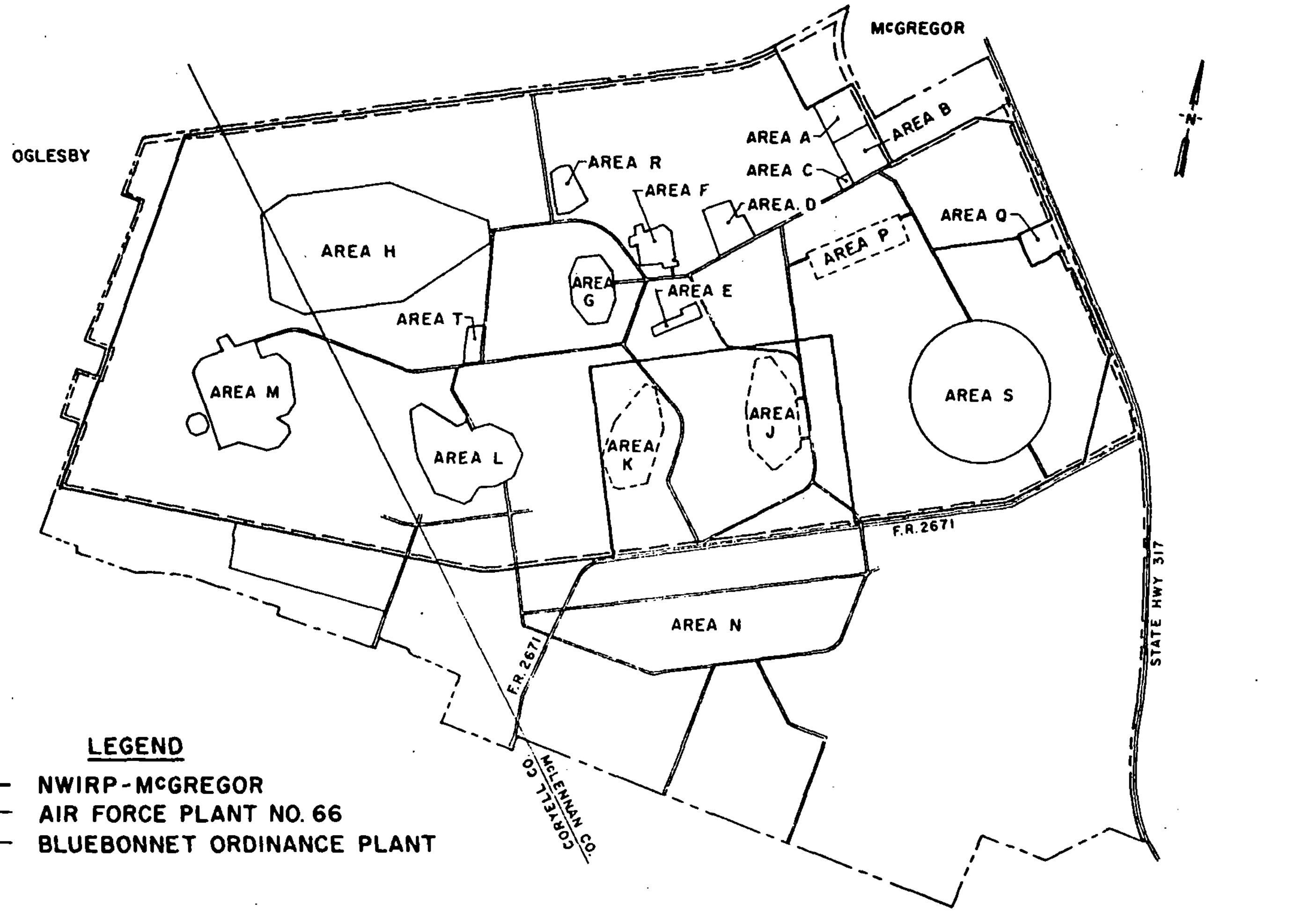
5.3 PHYSICAL FEATURES

5.3.1 Climatology

The NWIRP-McGregor site has a humid subtropical continental climate. Summers are long with high temperatures, while winters are short and mild. In the six winter months (November through April), the average low temperature is 44.2°F and the average high temperature is 65.7°F. For the six summer months the average low is 68.7°F and the average high 89.9°F. The annual average low temperature is 56.4°F with the average annual high temperature 77.8°F. The average daily temperature is 67.1°F. The extremes are -5°F (1949) and 112°F (1969). See Table 5-1 for a summary of climatological data.

The amount of precipitation in any one year is extremely variable. Most rainfall is the result of thunderstorm activity; consequently, considerable spatial variation in amounts occurs. There is an average of 77 days per year with precipitation, but much of the precipitation in any one year is concentrated in just a few thunderstorms. For example, in 1979 the yearly precipitation was 42.37 inches, and of this amount 20.26 inches, or 48.90 percent of the total annual precipitation, occurred in twelve days. Total annual rainfall has ranged from 60.20 inches (1905) to only 13.30 inches (1917), with the average annual precipitation being 31.26 inches. April and May are normally the wettest months, with July and August being the driest. There is no appreciable amount of snowfall in the area.

Evaporation rates are high in relation to annual precipitation. For example, in 1980 the pan evaporation rates for March through November totalled 81.7 inches compared to the average annual precipitation of only 31.26 inches. Much of the precipitation is evaporated which serves to reduce the possibility of leachate production and contamination migration.



LEGEND

- NWIRP-McGREGOR (solid line)
- AIR FORCE PLANT NO. 66 (dashed line)
- BLUEBONNET ORDINANCE PLANT (dash-dot line)

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NOTE: The acreage inside Areas J and K was not re-established by the Air Force.

NWIRP-McGREGOR
PROPERTY BOUNDARY LINES

FIGURE 5-3

TABLE 5-1
SUMMARY OF CLIMATOLOGICAL DATA

	Temperature (°F)					Precipitation (inches)					Wind		Mean Number of Days			
	Normal			Extremes												
Months	Daily Max.	Daily Min.	Monthly	Record Highest	Record Lowest	Normal	Maximum Monthly	Minimum Monthly	Max. in 24-hr	Relative Humidity (%)	Mean Speed (mph)	Prevailing Direction	Precip. (0.01 inch or more)	Thunderstorms	90°F & Above	32°F & Below
(a)				37	37		37	37	37	16	30	14	36	36	16	16
Jan	57.4	36.6	47.0	88	-5	1.87	5.83	0.03	2.24	71.25	11.9	S	7	1	0	14
Feb	61.5	40.3	50.9	90	5	2.38	4.55	0.17	3.03	68.25	12.2	S	7	2	0	8
Mar	68.4	46.0	57.2	100	15	2.36	6.84	0.04	3.07	65.5	13.3	S	7	4	1	2
Apr	77.8	56.8	67.3	101	27	4.02	13.37	0.65	5.09	69.25	13.2	S	8	6	1	0
May	84.4	64.5	74.5	99	45	4.60	15.00	0.72	7.18	71.0	12.1	S	9	8	6	0
Jun	91.9	71.8	81.9	104	52	2.73	12.06	0.27	4.21	64.75	11.8	S	6	5	22	0
Jul	96.2	75.0	85.6	108	61	1.47	8.58	T	4.49	59.0	10.8	S	4	4	28	0
Aug	96.7	74.7	85.7	112	60	1.81	8.91	T	4.80	60.75	9.9	S	5	5	28	0
Sep	89.5	68.3	78.9	106	48	3.19	7.29	0	4.57	67.5	9.5	S	6	4	15	0
Oct	80.4	57.7	69.1	101	32	2.55	9.36	0	5.72	67.25	10.0	S	5	3	3	0
Nov	68.7	46.2	57.5	92	17	2.27	6.24	0.13	4.26	69.25	10.9	S	6	2	0	2
Dec	60.6	39.1	49.8	91	14	2.01	7.03	0.04	3.11	69.5	11.3	S	6	1	0	9
Year	77.8	56.4	67.1	112	-5	31.26	15.00	0	7.18	66.75	11.4	S	77	45	104	35

NOTES: [a] Length of record (years).

The average relative humidity is 66.8 percent. Prevailing wind direction is from the south throughout the year.

5.3.2 Topography

The NWIRP-McGregor site is situated in the Cretaceous Prairie region of north central Texas. The Cretaceous Prairie is further divided into two great physiographic prairies: the Blackland Prairie, and the Grand Prairie. The chief difference between these two prairies is that the Grand Prairie has developed on firm resistent limestone, and the Blackland Prairie has developed on much less resistent clays and shales.

The NWIRP-McGregor site is located in the eastern most portion of the Grand Prairie, with the Blackland Prairie located to the south and east. In general, the surface of the Grand Prairie is composed of gently sloping, almost level, dip plains, broken only by the drainageways. The Grand Prairie is a hard-rock prairie underlain mainly by limestone of the Washita Group, and the area is also referred to as the Washita Prairie. The Grand Prairie is characterized by shallow calcareous soils.

The surface features, or landscape, of the NWIRP-McGregor site roughly parallels the underlying bedrock. The topography of the site is gently undulating with slopes ranging from nearly level to five percent. Drainage for the site is provided by tributaries of Harris Creek, Station Creek, and the South Bosque River. All of the streams within the site's boundary are intermittent. A more detailed description of the surface water characteristics of the site is included in the hydrology section.

5.3.3 Geology

The geologic formations underlying the whole of central Texas are of Cretaceous age. All of central Texas was covered by an advance of the sea during Cretaceous time, resulting in the present sequence of geologic units. Table 5-2 shows the geologic units which occur in central Texas. These Cretaceous aged rocks have been divided into two series, Gulfian and Comanchean, with the Gulfian being the younger. Within the boundaries of the NWIRP-McGregor site the Gulfian series is not present, but it does occur southeast of the site. This absence is the result of a regression of the sea during late Cretaceous time which shifted the sea east of the NWIRP-McGregor site. A geologic section of the area is shown in Figure 5-4.

The geologic units within the boundary of the NWIRP-McGregor site, due to the absence of the Gulfian series, all belong to the Comanchean series. The Comanchean series is further divided into three groups from the oldest to the youngest; The Trinity group, the Fredricksburg group, and the Washita group. Only the Washita group crops out in the vicinity of the NWIRP-McGregor site.

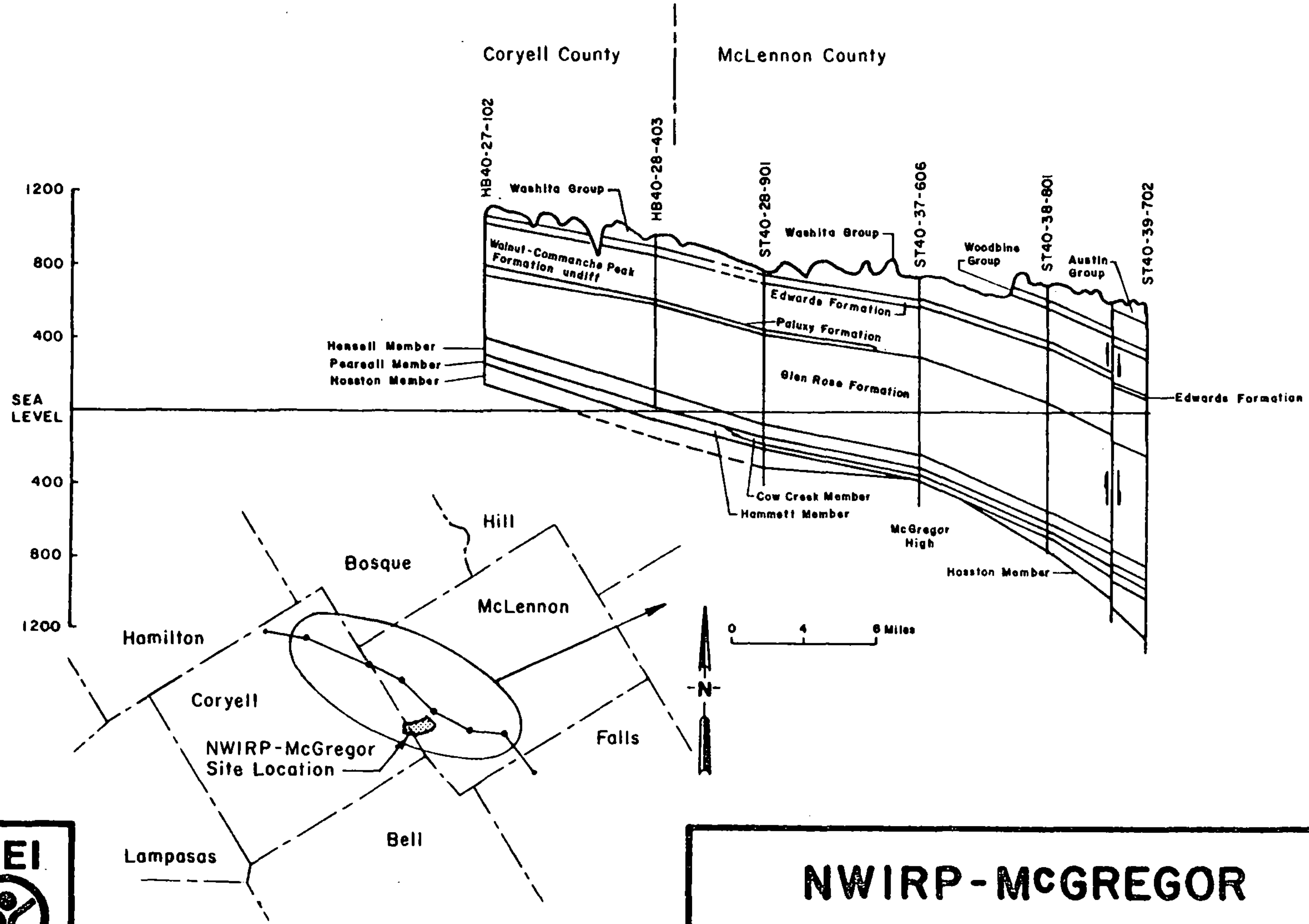
Within the Washita group (see Table 5-2) only the Georgetown formation crops out within the boundaries of the NWIRP-McGregor site. The Buda formation is not present in the vicinity of the site, and the Del Rio formation crops out just southeast of the site.

TABLE 5-2

GEOLOGIC UNITS OF CENTRAL TEXAS

SYSTEM	SERIES	GROUPS	FORMATIONS		THICK-NESS(ft)	MEASURED SECTIONS
CRETACEOUS	GULFIAN	EAGLE FORD	South Bosque		none	none included
			Lake Waco		55	
			Pepper		45	
	COMANCHEAN	WASHITA	Buda		none	
			Del Rio		45	
			Georgetown	Main Street	35	
				Pawpaw	7	
				Weno	36	
				Denton	6	
				Fort Worth	22	
				Duck Creek	29	
				Kiamichi	4	
		FREDERICKSBURG	Edwards		40	
			Comanche Peak		120	
			Walnut		150	
			Paluxy		20	
			Glen Rose		460	
		TRINITY	Hensel			
			Pearsall			
			Sligo			
			Hosston			

(Thornhill 1980)



NWIRP-McGREGOR
GEOLOGIC SECTION

FIGURE 5-4

The Georgetown formation is divided into seven units from the oldest to the youngest: Kiamichi, Duck Creek, Fort Worth, Denton, Weno, PawPaw, and Main Street. The two oldest units, Kiamichi and Duck Creek, do not crop out in the area of the site. The other units of the Georgetown formation do crop out within the boundary of the site. Figure 5-5 (fold-out in back of report) shows the geologic outcrop pattern at the NWIRP-McGregor site.

Brief descriptions of each of the outcropping units follow.

5.3.3.1 Main Street Limestone - The Main Street Limestone consists of medium hard, resistent, white, fine to medium crystalline, nodular limestone (Bassett, 1969). The lower limit of the Main Street Limestone is marked by the marly, less resistant beds of the Pawpaw member. Within the McGregor Quadrangle the Main Street Limestone is about thirty-five feet thick (Bassett, 1969). The Main Street Limestone is an impermeable unit (Bishop, 1977).

Outcrops of the Main Street Limestone occur throughout the vast majority of the NWIRP-McGregor site. Areas in which it crops out are as follows: Areas A & C (Administration and Industrial Security), Area D (Machine Shop & Tool Fabrication), Area E (Receiving, Warehousing & Vehicle Maintenance), Area F (Engineering Laboratories and Pilot Production), Area G (Tooling and Equipment Storage), Area H (Storage Magazines), Area L (Static Testing), and Area S (Explosives Disposal). Most of Area M (Manufacturing) also has Main Street Limestone cropping out.

5.3.3.2 Pawpaw Shale - The Pawpaw Shale bed is seven feet thick in the McGregor Quadrangle (Bassett, 1969). The Pawpaw shale unit weathers into three zones. The top and bottom two feet contain marly limestone that is easily weathered, while the middle three feet weather less quickly and remain as a resistant ledge. The Pawpaw shale crops out in isolated areas throughout the McGregor site. The only operation areas with outcrops of Pawpaw shale are parts of Areas M (Manufacturing) and R (Environmental and Static Testing).

5.3.3.3 Weno Limestone - Weno Limestone in the McGregor Quadrangle is approximately thirty-six feet thick (Bassett, 1969). The upper seventeen feet consist of nodular, bedded limestone with alternating thin marl beds. The lower nineteen feet have several unconsolidated marl beds. The base of the Weno limestone is a very resistant limestone ledge known as the Ocee ledge and is easily differentiated from the underlying Denton formation. The Weno Limestone is the second most frequently occurring outcrop at the NWIRP-McGregor site. It crops out near Areas M (Manufacturing) and R (Environmental and Static Testing). It also has an area of outcropping on the eastern boundary of the site.

5.3.3.4 Denton Marl - The Denton Marl is approximately six feet thick in the McGregor Quadrangle (Bassett, 1969). It is composed of dark gray soft marl which has several discontinuous thin limestone ledges near the center. The Denton Marl crops out in one isolated area southeast of Area M (Manufacturing).

5.3.3.5 Fort Worth Limestone - The Fort Worth Limestone is twenty-two feet thick in the McGregor Quadrangle (Bassett, 1969). It consists of fairly uniform, nodular limestone with interbedded thin shale layers. The Fort Worth Limestone crops out in only one small area at the site, just southeast of Area M (Manufacturing).

Upon weathering, all the outcropping units of the Georgetown formation, exclusive of the Main Street member which is already hard and impermeable, become impermeable (Bishop, 1977). This is a result of the clays in these units which are released during weathering. These clays form an effective seal to downward percolation of water.

The deeper geologic formations underlying the NWIRP-McGregor site belong to the Fredricksburg and Trinity Groups of the Commanchean series. The Fredricksburg Group is characterized by limestones and shales with some intermixing of siltstones, clay, and sand. The upper member of the Fredricksburg group is the Edwards Limestone formation, and it occurs just beneath the Washita Group. The Edwards Limestone has a high permeability because of its high porosity (Bishop, 1977). This unit can provide water in pumpable quantities.

The deeper lying Trinity Group is characterized by limestones and shales. The Trinity Group also has deposits of sand which serve as regional aquifers, providing much of the water for central Texas.

In the vicinity of the NWIRP-McGregor site, the depth to the underlying bedrock is very shallow. The soil is seldom more than five or six feet thick, and is often much less. The geologic formations underlying the site are relatively flat. These beds have a dip of twenty to twenty-five feet per mile to the southeast and a strike of north 6° east (Bassett, 1969).

5.3.4 Soils

The soils of the Grand Prairie, in which the NWIRP- McGregor site is located, are residual soils which have developed from the underlying limestones which are intermixed with marl. This is in contrast to soils of the nearby Blackland Prairie which have developed from shales and clays.

The soils of the NWIRP-McGregor site are characterized by a mixture of deep and shallow clays on limestone. The dominant soils are reddish-brown to black crumbly clays of the Denton, San Saba, Tarrant, and Crawford series. These soils can be classified as vertisols, and expand and contract in relation to the soil moisture. When wet, the clay content of these soils provides a fairly impermeable barrier to downward leaching. However, when these soils dry out, they develop vertical cracks which could extend to the shallow underlying bedrock. The depth of soil over the bedrock is variable, but seldom exceeds five or six feet. Figure 5-6 (foldout in pocket) represents a soils map of the NWIRP-McGregor site.

Portions of the site are also covered with alluvial soils. Most of the alluvial soils are composed of loose, light brown calcareous fine sand. There are some low, flat areas where dry loam or clay prevails.

A brief description of the common soil series which occur at the NWIRP-McGregor site follows.

5.3.4.1 Denton Series - The Denton series consists of dark-brown to dark grayish-brown, mostly calcareous, very crumbly soils underlain by limestones at various depths. These are the most extensive soils of the Grand Prairie. These soils are typically from 18 to about 40 inches deep over limestone. The Denton soils are well drained and have medium to rapid surface runoff. They are moderately susceptible to erosion. The permeability of the Denton soils ranges from 0.06-0.2 inches per hour, which is classified as slow. The clay content ranges from 35-55 percent. The shrink-swell potential of the Denton soils is high, which means these soils can have a volume change of more than 6 percent depending upon the moisture.

5.3.4.2 Crawford Series - The Crawford series is made up of dark-brown to reddish-brown noncalcareous clays. These clays are similar to the Denton soils in many respects, but are finer textured, somewhat less grayish, and usually more reddish in the subsoil. The Crawford soils are well drained with slow to medium runoff. The Crawford soils are slightly susceptible to erosion. Permeability of these soils is less than 0.06 inches per hour, which is classified as very slow. However, when dry and cracked the permeability is rapid. The clay content ranges from 40-60 percent in the Crawford soils. The shrink-swell potential for these soils is rated as very high, meaning a volume change of more than 9 percent is possible.

5.3.4.3 San Saba Series - The San Saba series consists of very dark-gray to black crumbly clays underlain by limestone. These soils are the darkest of those on the Grand Prairie. The San Saba soils are moderately well drained with slow to medium runoff, and these soils are not very susceptible to erosion. Permeability is less than 0.06 inches per hour in the San Saba soils, which is classified as very slow. However, when dry and cracked the permeability is rapid. The clay content ranges from 45-65 percent. The shrink-swell potential of the San Saba soils is very high, meaning a volume change of more than 9 percent is possible as moisture conditions change.

5.3.4.4 Tarrant Series - The Tarrant series is comprised of dark-colored, very shallow soils on limestone. It is the very shallow associate of the Denton series and occurs extensively throughout the Grand Prairie. Runoff on these soils is medium to rapid, and internal drainage is medium. These soils are slightly susceptible to erosion. Permeability of the Tarrant soils ranges from 0.2-0.6 inches per hour, which is classified as moderately slow. The clay content of these soils ranges from 40-60 percent. The shrink-swell potential of the soils is low, meaning a volume change of less than three percent.

Detailed accounts of each of the soils which occur within the boundary of the NWIRP-McGregor site, including representative profiles, are included in Appendix A. Also included in Appendix A are soil borings from Areas M(Manufacturing) and L(Static testing) which are representive of the NWIRP-McGregor site as a whole.

5.3.5 Hydrology

5.3.5.1 Surface Water - Surface water at the NWIRP-McGregor site is provided by tributaries of Station Creek, Harris Creek, and the South Bosque River. The site can be divided into three watersheds which correspond to these streams. Figure 5-7 shows the watersheds within the boundaries of the NWIRP-McGregor site, and indicates the direction of surface water flow. On a regional basis, the entire NWIRP-McGregor site lies within the Brazos River Basin. All of the streams within the boundaries of the site are intermittent in nature, and are subject to drying up during periods of drought. Many of the tributaries flow only following periods of rain. Surface waters within the boundaries of the site, and in the surrounding areas, are used solely for agricultural purposes, mainly as water for livestock. All water used for human and industrial purposes comes from groundwater. The surface water is hard, which is a result of the limestone bedrock. Descriptions of the three watersheds which occur at the site follow.

5.3.5.1.1 Station Creek Watershed: The Station Creek Watershed is located in the western most portion of the NWIRP-McGregor site, and encompasses roughly 1/5 of the land area. This portion of the site drains southward into Station Creek, which contrasts to the rest of the site which drains eastward. Drainage from Station Creek flows into the Leon River Watershed, which in turn flows into the Little River Watershed, which empties into the Brazos River.

Surface drainage from Area M(Manufacturing) enters into Station Creek. This would include any overflow from the interior settling ponds, the propellant washout pond, the north stock pond, and the Imhoff settling ponds.

5.3.5.1.2 Harris Creek Watershed: The Harris Creek Watershed occupies roughly the northern portions of the NWIRP-McGregor site. This portion of the site drains northeastward into Harris Creek. Drainage into Harris Creek flows into the South Bosque Watershed, which then empties into the Brazos River.

A large number of the site's operating areas drain into tributaries of Harris Creek. These include Areas D(Machine Shop and Tool Fabrication), F(Engineering Laboratories and Pilot Production), G(Tooling and Equipment Storage), H(Storage Magazines), R(Environmental and Static

Testing), T(Crating and Shipping), and portions of Areas A(Administration) and L(Static Testing). Drainage into Harris Creek includes effluent from the three settling ponds in the western portion of Area F, as well as any effluent from the two presently dry ponds in the northeastern portion of Area F. Drainage from the pesticide spill site in Area G (described later) also enters Harris Creek.

5.3.5.1.3 South Bosque Watershed: The South Bosque Watershed occupies the southern portions of the NWIRP-McGregor site. This portion of the site drains southeastward into the South Bosque River. The South Bosque River subsequently empties into the Brazos River.

Operating areas which drain into the South Bosque River include Areas E(Warehousing and Garage), S(Explosives Disposal), and portions of Area L(Static testing). Surface drainage from the asbestos site (described later) drains into the South Bosque River. Areas J and K, which were old WWII bomb loading lines but are now in private ownership, also drain into the South Bosque River. Discharge from the City of McGregor's Sewage Disposal plant, old Area Q, also drains into the South Bosque River.

5.3.5.2 Groundwater - Groundwater is the source for all potable and process water used at the NWIRP-McGregor site, and in the areas surrounding the site. Regionally, much of central Texas relies on groundwater for all or a substantial portion of their drinking and industrial water.

Groundwater in central Texas is obtained from two main aquifers. These aquifers are located within the Trinity division and are known as the Hensel aquifer and the Hosston aquifer. These aquifers are commonly referred to as the "Upper Trinity Sand" and "Lower Trinity Sand", respectively. These two aquifers are composed of fine to coarse sand, and are separated by beds of limestone and shale.

The water in these two aquifers moves generally from the northwest to the southeast. The rate of groundwater movement, in both aquifers, varies from about 10 to 40 feet per year (Thornhill, 1980). The hydraulic gradient of the two aquifers is between 10 and 25 feet per mile (Thornhill, 1980). The average transmissibility values are about 7,500 gpd/ft within the Hosston, and 2,000 gpd/ft for the Hensel (Thornhill, 1980). Permeability values for these two aquifers average 60 gpd/sq.ft. and porosity averages 20-35 percent (Thornhill, 1980).

The Hensel aquifer is the only available source of groundwater in sufficient enough quantities for the NWIRP-McGregor site. This is unlike the surrounding areas of central Texas which also have access to the Hosston aquifer. The absence of the Hosston aquifer results from the fact that the NWIRP-McGregor site is situated on what is called the McGregor High. This is an erosional high where non-deposition occurred during early Cretaceous time. This high was probably a Paleozoic limestone ridge which existed as an island during early Cretaceous time. As a result of this high, there is a marked decrease in the thickness of the lower Cretaceous rocks, resulting in a lack of the Hosston aquifer under the

NWIRP- McGregor site. This high also serves to restrict the movement of groundwater through this area in the Hosston aquifer.

The NWIRP-McGregor site obtains its water from four wells which are drilled into the Hensel aquifer (Figure 5-8). These wells were drilled in 1942 when the site was the Bluebonnet Ordnance Plant. The Hensel aquifer is located some 960 feet below the surface of the site, and ranges from 19-100 feet in thickness. The four wells range in depths from 1011-1140 feet, and provide all the potable and process water used on the site. Appendix B contains the drilling logs for these wells. These logs provide a good record of the underlying geologic units.

Table 5-3 provides relevant data on the site's four wells; including the pumping rate(gpm), static water level, pumping water level, drawdown, and specific capacity. This table also shows the changes which have occurred over the course of the almost forty years during which the wells have been operational. As is evidenced by this table, there has been a significant lowering of the pieziometric surface from 175 feet beneath the surface in 1942 to 588 feet as of 1979. This represents a drop of 413 feet in forty years. The pieziometric surface is continuing to drop at an average of 10 ft/yr (Thornhill, 1980).

Water usage averages 260,000 gallons per day at the NWIRP-McGregor site (ManTech, 1976). This high usage, coupled with the fact that there is almost no recharge into the aquifer, has led to the drastic lowering of the water level. The areas of recharge for the Hensel aquifer occur some 80 miles to the west of the site in Hood and Erath counties. Assuming the groundwater moves at the fastest rate of 40 feet per year, it would take over 10,000 years for recharge to reach the NWIRP-McGregor site. The nearest discharge area occurs in Travis County, some 75 miles to the southeast.

The Hensel aquifer in the general area of the NWIRP-McGregor site has relatively good water quality. Dissolved solids are in the range of 650-750 mg/l which is somewhat high, but is still classified as fresh water. Total hardness is in the range of 20- 50 mg/l, which is classified as soft water. Contained in Appendix B is a detailed chemical analysis of the groundwater from the four on-site wells.

In addition to the deep wells of the Hensel aquifer, which supply all the potable and industrial water for the site and surrounding areas, there are numerous hand-dug shallow wells. Figure 5-8 shows the approximate locations of some of these shallow wells (numerous others exist), as well as the location of the deep Hensel aquifer wells.

The fact that these shallow wells exist indicates that there is a high water table in the area. The soil borings in Appendix A also indicate there is a high water table for the area. These borings show a water table at a depth of 15-20 feet below the surface. Many of these shallow wells yield water only seasonally, but others yield water continuously.

TABLE 5-3

WELL INFORMATION

		(801) Well 1	(802) Well 2	(803) Well 3	(804) Well 4
Elevation (ft)		744	754	769	781
Measured (gpm)/ Discharge Pressure (ft)	1942	350/-	375/-	240/-	420/-
	1955	350/84	370/51	195/29	430/19.6
	1965	300/85	280/65	200/35	420/18
	1969	370/42	430/51	200/85	570/18
	1977	325/60	430/55	192/21	480/20
	1979	280/50	305/44	206/30	475/20
Static Level (ft)[a]/ Pumping Level (ft)	1942	175/-	216/-	240/-	250/-
	1965	410/610	417/545	-	414/485
	1969	442/638	447/625	480/625	463/547
	1977	493/686	503/660	525/665	528/595
	1979	588/714	552/677	590/743	586/636
Drawdown (ft)/ Specific Capacity (ft)	1965	200/1.6	128/218	-/1.22	71/5.84
	1969	195/1.89	168/2.52	145/1.38	84/6.79
	1977	193/1.68	156/2.79	140/1.37	67/7.16
	1979	126/2.22	125/2.44	153/1.35	70/6.79
Pump Setting (ft)[a]	1942	400	400	440	400
	1955	560	540	560	480
	1957	610	590	620	570
	1969	700	660	680	630
	1979	885	885	820	770
Begin Hensel Aquifer[a]		971	960	962	957
Thickness of Sands (ft)		51	19	30	100
Well Depth (ft)[a]		1,141	1,046	1,011	1,062

NOTE: [a] Depth below surface

Movement of this upper groundwater would approximately follow the contours of the surface. Most of these hand-dug shallow wells are located in the vicinity of streams. Water from these wells is presently used solely for agricultural purposes, either for crops or for livestock. This is due mainly to the unreliability of the shallower groundwater and the general poor quality of the water.

Much of this shallow groundwater may occur as a lense in the upper few feet of bedrock. The upper few feet of bedrock, mainly limestone, is likely to be more fractured and creviced than the deeper bedrock. These fractures and crevices would allow water to permeate into this upper few feet of limestone. The borings in Appendix A seem to agree with this reasoning. In boring #2, fractures were noted at a depth of 14 feet. In borings #4,5, and 6, water circulation was lost at a depth of 13 to 14-1/2 feet, indicating fractures in the bedrock.

Table 5-4 provides a summary of the aquifer properties in the geologic units in McLennan County. As this table indicates, most of the geologic units underlying the site, with the exception of the Hensel and Hosston, do not yield water. One other exception to this is the Edwards formation which is a permeable limestone and does yield water in places. The Edwards formation occurs at a depth of some 130 feet below the NWIRP-McGregor site.

5.3.6 Migration Potential

5.3.6.1 Surface Water - Contamination of the surface water at the NWIRP-McGregor site is a possibility. However, this likelihood is minimized by the intermittent nature of the site's streams. The rate of flow from the site is thus extremely variable. Much of the surface discharge into the site's streams percolates into the stream bed or evaporates before it leaves the boundaries of the site. Surface contamination migration, while possible, is probably extremely slow.

Surface water contamination from the streams in the Harris and South Bosque watersheds would migrate to the east, ultimately ending up in Lake Waco which flows into the Brazos River. Surface water contamination from the Station Creek watershed migrates to the south into the Leon River, which flows into the Little River, which empties into the Brazos River southeast of the site some 50 miles.

5.3.6.2 Shallow Groundwater - The shallow groundwater, which is indicated by the high water table, could very easily become contaminated. The water occurs less than 20 feet beneath the surface of the site. This shallow depth, coupled with the vertisol soils of the site, makes contamination a real possibility. These vertisol soils are subject to developing vertical cracks upon drying, and these cracks provide an avenue for contamination migration into the shallow groundwater. Seepage through the thin soils is also possible. The flow of this shallow groundwater would closely approximate that of the surface topography.

TABLE 5-4

SEQUENCE AND CLASSIFICATION OF CENTRAL TEXAS GEOLOGIC FORMATIONS

System	Series, group, or division			Formation or member		Maximum Thickness (feet)	Description	Aquifer properties
Quaternary	Recent and Pleistocene			Alluvium and terraces		?	Sand, silt, and gravel.	Yields potable water in some areas at shallow depth.
Cretaceous	Gulfian Series			Taylor		1170	Calcareous marls, sandy marls, lenses of calcareous sandstone, and chalky limestone.	Yields some potable water from Wolfe City member in eastern part of county at shallow depth.
				Austin		295	Marly limestone and limy shale with some bentonite seams.	Not known to yield water in McLennan County.
		Eagle Ford Group		South Bosque		140	Shale with limestone flags.	Yields no water in McLennan County.
				Lake Waco		145	Shale with limestone flags and bentonite seams.	Yields small amounts of water for domestic use in western part of McLennan County.
				Pepper		100	Non-calcareous shale with injected sandstone dikes in northern part of McLennan County.	Reported to yield some potable water in northeastern McLennan County.
	Comanchean Series	Washita Division		Buda		35	Hard to chalky fossiliferous limestone.	Yields no water in McLennan County.
				Del Rio		85	Fossiliferous clay with occasional limestone beds and sandy streaks.	Yields no water in McLennan County.
				Georgetown		210	Nodular limestones and marly shales.	Not known to yield water in McLennan County.
		Fredericksburg Division		Edwards		45	Limestone, rudistid reef material, and calcareous siltstone.	Yields some potable water in northwestern McLennan County.
				Comanche Peak		130	Nodular limestones and fossiliferous clay.	Yields no water in McLennan County.
				Walnut		175	Shale with some limestone and sand stringers.	Yields no water in McLennan County.
				Paluxy		20	Sands with some shales interbedded.	Yields potable water in northwestern McLennan County.
		Trinity Division	Upper	Glen Rose		800+	Alternating limestones and shales with some anhydrite.	Yields some water in McLennan County.
				Hensel		75	Fine to coarse sands with green shales.	Principal aquifer in western McLennan County. Yields large supplies for municipal, industrial, and domestic purposes.
			Middle	Pearsall Formation	Cow Creek	75	Limestone and shales.	Yields no water in McLennan County.
					Hammett	100	Shale with some limestone and sand.	Yields no water in McLennan County.
			Lower	Sligo		95	Limestone and shale.	Yields no water in McLennan County.
				Hosston		800+	Fine to coarse sand with some conglomerate and varicolored shale.	Principal aquifer in eastern McLennan County. Yields large supplies for municipal and industrial purposes. Water in sands in upper part of formation in southeastern part of county may be highly mineralized.
Jurassic	Cotton Valley Group			Schuler (?)		?	Sands and shales (?).	Yields no water in McLennan County.
Pennsylvanian (?)				?		?	Shales and metamorphics.	Yields no water in McLennan County.

(Rupp 1976)

5.3.6.3 Hensel Aquifer - Contamination of the Hensel aquifer is extremely unlikely due to its depth beneath the site and the impermeability of much of the underlying bedrock. Potential contamination would have to travel vertically some 1000 feet, through impermeable limestone and shale, in order to reach the Hensel aquifer.

The Hensel aquifer is a regionally important source of water, and any contamination would represent a serious problem. If by some chance contamination were to reach the aquifer, it would travel in a southeast ward direction from the site at a rate of 10-40 feet per year (Thornhill, 1980). This means it would take 132-528 years for the contamination to migrate one mile. The nearest discharge area for the Hensel aquifer is some 75 miles away in Travis County. It would take the groundwater some 9,900-39,600 years to migrate there.

5.3.6.4 On Base Migration - The possibility of on-base migration from off-base sources is extremely unlikely. Surface water or shallow groundwater contamination onto the site would come from areas west or northwest of the site (see figure 5-7 for surface drainage characteristics). Oglesby is located in this area, but it is a small town which presents no contamination threat to the NWIRP-McGregor site. The other areas which have surface and shallow groundwater migrating onto the site are all agricultural. These agricultural areas only present problems in terms of the fertilizers, pesticides, and herbicides they use. These do not represent a serious problem at the NWIRP-McGregor site. The fertilizer use may be increasing the nitrogen levels in the shallow groundwater, but this is not an isolated problem. These same types of chemicals are being applied on the agricultural land throughout the region both on-site and off-site.

5.4 BIOLOGICAL FEATURES

5.4.1 Flora

Historically, the area of the NWIRP-McGregor site has been a mid to short grass prairie. Grasses which are common in the area include the following: Buffalo, hairy grama, Texas grama, side-oats grama, three-awn, and little bluestem. Soils suitable for cultivation have historically been cultivated. Areas where the natural vegetation has been disturbed, and subsequently left unattended, usually grow up in Johnson grass and weeds. Along streams and drainageways hackberry, bois d'arc, and willows can occur. Live-oak are also scattered throughout many areas. Rough stony land supports Spanish oak, shinnery white oak, ash, red bud, and various other small trees and shrubs.

The project area lies at the juncture of three major vegetational areas - post oak savannah, blackland prairies, and cross-timbers and prairies. These three areas, while they share many dominant species (such as big and little bluestem and a number of xerophytic oaks), differ markedly in rare and endangered plant species reported. Tables 5-6 and 5-7 list Nationally Endangered and Threatened Plants for Texas. Table 5-5 lists Federally and State-listed Endangered and Threatened Plant Species categorized by the three vegetation areas of concern. The principal

TABLE 5-5

ENDANGERED AND THREATENED FLORA OF THE VEGETATIONAL AREAS IN THE McGREGOR REGION

POST OAK SAVANNAH:

SPECIES	STATUS[a]
Agave virginica (Polianthes virginica)	T
Arisaema dracontium	T
Asclepias tomentosa	T
Betula nigra	T
Castanea dentata	E
Eustoma grandiflorum	T
Arundinaria gigantea	T
Leersia oryzoides	T
Stipa avenacea	T
Iris virginica var. shrevei	T
Brazoria pulcherrima	T
Salvia azurea	E
Amorpha canescens	T
Amorpha fruticosa var. angustifolia	T
Astragalus soxmaniorum	T
Erythronium albidum	T
Schoenocaulon texana	T
Calopogon barbatus	E
Corallorhiza wisteriana	T
Habenaria ciliaris	T
Habenaria repens	E
Spiranthes ovalis	T
Gilia rubra (Ipomopsis rubra)	T
Polygala cruciata	T
Woodwardia virginica	T
Dodecatheon meadia	T
Ceanothus americanus	T
Ceanothus herbacea	T
Penstemon cobaea	T
Penstemon murrayanus	T
Selaginella apoda	T
Viola missouriensis	T

BLACKLAND PRAIRIES:

SPECIES	STATUS[a]
Sagittaria brevirostra	T
Aster azureus	E
Vernonia vulturina	T
Calystegia sepium	T
Carex davisii	T
Phyllanthus nirori	T
Eustoma grandiflorum	E
Panicum linearifolium var. wernerii	T
Zizania texana	E
Apios americana	T
Dalea hallii	T
Psoralea reverchoni	T
Mirabilis eutrichig	T
Ophioglossum crotophoroides	E
Spiranthes parksii	T
S. vernalis	T
Cysopteris fragilis	T
Potamogeton panormitanus	T
Rosa ignota	T
Eryngium hookeri	T
Tauschia texana	T

CROSS-TIMBERS AND PRAIRIES:

SPECIES	STATUS[a]
Sagittaria brevirostra	T
Aster azureus	E
Calystegia sepium	T
Cucurbita texana	T
Carex davisii	T
Carex meadii	T
Bergia texana	T
Phyllanthus niruri	T
Eustoma grandiflorum	E
Panicum linearifolium var. wernerii	T
Astragalus nuttalianus var. macilentus	T
Psoralea reverchoni	T
Mirabilis eutrichia	T
Ophioglossum crotophoroides	E
Hexalectris spicata	E
Spiranthes parksii	T
Potamogeton panormitanus	T
Dodecatheon meadia	T
Rosa ignota	T
Eryngium hookeri	T
Tauschia texana	T

NOTES: [a] T = State Threatened
E = State Endangered

TABLE 5-6

NATIONALLY ENDANGERED PLANTS AS LISTED IN THE FEDERAL REGISTER FOR TEXAS, JUNE 16, 1976

AIZOACEAE (Carpetweed Family)
- o Sesuvium trianthemoides

ASCLEPIADACEAE (Milkweed Family)
- Matelea edwardsensis
- o Matelea radiata
- Matelea texensis

ASTERACEAE (Aster Family)
- Ambrosia cheiranthifolia
- Brickellia viejensis
- Coreopsis intermedia
- Dyssodia tephroleuca
- Erigeron geiseri var. calcicola
- Grindelia oolepis
- Helianthus paradoxus
- o Hymenoxys texana
- Machaeranthera aurea
- Perityle bisetosa var. bisetosa
- Perityle bisetosa var. scalaris
- Perityle cinerea
- Perityle lindheimeri var. halmifolia
- o Perityle rotundata
- Perityle vitreomontana
- Viguiera ludens

BRASSICACEAE (Mustard Family)
- Leavenworthia aurea
- Lesquerella valida
- Selenia jonesii
- Streptanthus sparsiflorus
- o Thelypodium tenue
- Thelypodium texanum

BROMELIACEAE (Pineapple Family)
- o Hechtia texensis

CACTACEAE (Cactus Family)
- Ancistrocactus tobuschii
- Coryphantha minima
- Coryphantha ramillosa
- Coryphantha scheeri
  - o var. uncinata
- Coryphantha sneedii
  - oo var. sneedii
- Coryphantha strobiliformis var. durispina
- Echinocereus chloranthus var. neocapillus
- Echinocereus lloydii
- Echinocereus reichenbachii var. albertii
- Echinocereus russanthus
- Echinocereus viridiflorus var. davisii
- Neolloydia gautii
- Neolloydia mariposensis
- Opuntia strigil
  - o var. flexospina

CARYOPHYLLACEAE (Pink Family)
- o Arenaria livermorensis
- Cerastium clawsonii
- Paronychia congesta
- Paronychia maccartii
- Silene plankii

CHENOPODIACEAE (Goosefoot Family)
- Atriplex klebergorum
- Suaeda duripes

CISTACEAE (Rockrose Family)
- o Lechea mensalis

CRASSULACEAE (Orpine Family)
- Lenophyllum texanum

CYPERACEAE (Sedge Family)
- Eleocharis cylindrica

ERIOCAULACEAE (Pipewort Family)
- Eriocaulon kornickianum

EUPHORBIACEAE (Spurge Family)
- Andrachne arida
- Argythamnia aphoroides
- Argythamnia argyraea
- Euphorbia fendleri var. triligulata
- Euphorbia golondrina
- Manihot walkerae
- Phyllanthus ericoides

FABACEAE (Bean Family)
- Acacia emoryana
- Brongniartia minutifolia
- Calliandra biflora
- Genistidium dumosum
- Hoffmannseggia tenella
- Petalostemum reverchonii
- Petalostemum sabinale
- Vicia reverchonii

FAGACEAE (Beech Family)
- Quercus graciliformis
- Quercus hinckleyi
- Quercus tardifolia

FRANKENIACEAE (Alhali-Heath Fam.)
- Frankenia johnstonii

GENTIANACEAE (Gentian Family)
- Bartonia texana

HYDROPHYLLACEAE (Waterleaf Family)
- Phacelia pallida

ISOETACEAE (Quillwort Family)
- Isoetes lithophylla

LAMIACEAE (Mint Family)
- Brazoria pulcherrima
- o Hedeoma pilosum
- Physostegia correllii

LILIACEAE (Lily Family)
- Polianthes runyonii
- o Schoenolirion texanum

MALVACEAE (Mallow Family)
- Callirhoe scabriuscula
- Gaya violacea
- Hibiscus dasycalyx

ORCHIDACEAE (Orchid Family)
- o Spiranthes parksii

POACEAE (Grass Family)
- Muhlenbergia villosa
- Poa involuta
- Zizania texana

POLEMONIACEAE (Phlox Family)
- Phlox nivalis ssp. texensis
- Polemonium pauciflorum ssp. hinckleyi

POLYGALACEAE (Milkwort Family)
- Polygala maravillasensis
- Polygala rimulicola

POLYGONACEAE (Smartweed Family)
- Eriogonum nealleyi
- Eriogonum suffruticosum
- Polygonella parksii
- Polygonum texense

POTAMOGETONACEAE (Duckweed Family)
- Potamogeton clystocarpus

RANUNCULACEAE (Crowfoot Family
- Aquilegia chaplinei
- Aquilegia hinckleyana
- Ranunculus fascicularis var. cuneiformis

RHAMNACEAE (Buckthorn Family)
- Colubrina stricta
- Condalia hookeri var. edwardsiana

ROSACEAE (Rose Family)
- oo Rubus duplaris

RUTACEAE (Rue Family)
- Zanthoxylum parvum

SALICACEAE (Willow Family)
- Populus hinckleyana

SCROPHULARIACEAE (Figwort Family)
- Castilleja ciliata
- o Seymeria havardii

STERCULIACEAE
- o Nephropetalum pringlei

STYRACACEAE (Storax Family)
- Styrax platanifolia var. stellata
- Styrax texana

URTICACEAE (Nettle Family)
- Urtica chamaedryoides var. runyonii

VALERIANACEAE (Valerian Family)
- o Valerianella texana

o Indicates those species which have recently become extinct or possibly extinct in the continental United States (see listing below).

oo Indicates those species which were listed as threatened in the July 1, 1975 Federal Register but have been changed to endangered according to the June 16, 1976 Federal Register.

TABLE 5-7

NATIONALLY THREATENED PLANTS AS LISTED IN THE FEDERAL REGISTER FOR TEXAS, JULY 1, 1975

ACANTHACEAE (Acanthus Family)
- Dyschoriste crenulata
- Justicia runyonii
- Justicia warnockii
- Justicia wrightii
- Ruellia drummondiana
- Stenandrium fascicularis

ACERACEAE (Maple Family)
- Acer grandidentatum var. sinuosum

APIACEAE (Parsley Family)
- Aletes filifolius
- Eurytaenia hinckleyi

APOCYNACEAE (Dogbane Family)
- Amsonia Glaberrima
- Amsonia repens
- Amsonia Tharpii

ASCLEPIADACEAE (Milkweed Family)
- Matelea brevicoronata

ASTERACEAE (Aster Family)
- Aster scabricaulis
- Astranthium robustum
- Bahia bigelovii
- Brickellia brachyphylla var. hinckleyi
- Brickellia brachyphylla var. terlinguensis
- Brickellia dentata
- Brickellia leptophylla
- Brickellia shineri
- Chaetopappa hersheyi
- Cirsium turneri
- Erigeron bigelovii
- Helianthus praecox ssp. hirtus
- Liatris cymosa
- Liatris tenuis
- Perityle warnockii
- Porophyllum greggii
- Senecio warnockii
- Solidago mollis var. angustata

BERBERIDACEAE (Barberry Family)
- Berberis swaseyi

BETULACEAE (Birch Family)
- Ostrya chisosensis

BORAGINACEAE (Borage Family)
- Cryptantha crassipes
- Onosmodium helleri

BRASSICACEAE (Mustard Family)
- Arabis petiolaris
- Lesquerella angustifolia
- Lesquerella mcvaughiana
- Lesquerella thamnophila
- Streptanthis bracteatus
- Streptanthus carinatus
- Streptanthus cutleri

CACTACEAE (Cactus Family)
- Coryphantha dasyacantha var. varicolor
- Coryphantha duncanii
- Coryphantha hesteri
- Coryphantha sulcata var. nickelsiae
- Echinocereus reichenbachii var. chisosensis
- Echinocereus reichenbachii var. fitchii
- Echinocereus viridiflorus var. correllii
- Epithelantha bokei

CACTACEAE (Continued)
- Neolloydia warnockii
- Opuntia arenaria
- Opuntia imbricata var. argentea
- Thelocactus bicolor var. flavidispinus

CAMPANULACEAE (Harebell Family)
- Campanula reverchonii

CAPPARIDACEAE (Caper Family)
- Cleome multicaulis

CAPRIFOLIACEAE (Honeysuckle Family)
- Symphoricarpos guadalupensis

CARYOPHYLLACEAE (Pink Family)
- Paronychia chorizanthoides
- Paronychia drummondii ssp. parviflora
- Paronychia nudata
- Paronychia virginica var. parksii
- Paronychia wilkinsonii

COCHLOSPERMACEAE (Cochlospermum Family)
- Amoreuxia wrightii

COMMELINACEAE (Spiderwort Family)
- Tradescantia edwardsiana
- Tradescantia wrightii

CRASSULACEAE (Orpine Family)
- Sedum robertsianum

CURCURBITACEAE (Squash Family)
- Cucurbita texana

CYPERACEAE (Sedge Family)
- Cyperus onerosus
- Eleocharis austrotexana

EUPHORBIACEAE (Spurge Family)
- Euphorbia innocua
- Euphorbia jejuna
- Euphorbia perennans
- Euphorbia roemeriana
- Euphorbia strictior
- Tragia nigricans

FABACEAE (Bean Family)
- Amorpha texana
- Astragalus mollissimus var. marcidus
- Caesalpinia brachycarpa
- Caesalpinia drummondii
- Coursetia axillaris
- Desmodium lindheimeri
- Sophora gypsophila var. guadalupensis

HYDROPHYLLACEAE (Waterleaf Family)
- Nama xylopodum
- Phacelia integrifolia var. texana

LAMIACEAE (Mint Family)
- Hedeoma apiculatum
- Physostegia micrantha
- Salvia penstemonoides

LILIACEAE (Lily Family)
- Agave chisoensis
- Allium perdulce var. sperryi
- Anthericum chandleri
- Polianthes maculosa
- Trillium texanum

LOGANIACEAE (Loganica Family)
- Spigelia texana

LYTHRACEAE (Loosestrife Family)
- Heimia longpipes
- Lythrum ovalifolium

MALVACEAE (Mallow Family)
- Abutilon marshii

MELASTOMATACEAE (Melastomé Fam.)
- Rhexia salicifolia

NYCTAGINACEAE (Four O'Clock Fam.)
- Acelisanthes crassifolia

ORCHIDACEAE (Orchid Family)
- Hexalectris grandiflora
- Hexalectris nitida
- Hexalectrix revoluta
- Plantanthera flava
- Plantanthera integra
- Polemonium pauciflorum ssp. hinckleyi

PEDALIACEAE (Pedalium Family)
- Proboscidea sabulosa

PLUMBAGINACEAE (Leadwort Fam.)
- Limonium limbatum

POACEAE (Grass Family)
- Bothriochloa exaristata
- Bromus texensis
- Chloris texensis
- Festuca ligulata
- Willkommia texana

POLYGONACEAE (Smartweed Family)
- Eriogonum correllii
- Polygonum striatulum
- Rumex spiralis
- Notholaena schaffneri var. nealleyi

RANUNCULACEAE (Crowfoot Family)
- Thalictrum debile

ROSACEAE (Rose Family)
- Crataegus berberifolia
- Crataegus stenosepala
- Crataegus sutherlandensis
- Crataegus warneri
- Prunus havardii
- Prunus minutiflora
- Prunus murrayana
- Prunus texana
- Rosa stellata

RUBIACEAE (Madder Family)
- Galium correllii

SAXIFRAGACEAE (Saxifrage Fam.)
- Philadelphus ernestii
- Philadelphus texensis var. texensis

SCROPHULARIACEAE (Figwort Fam.)
- Castilleja elongata

SOLANACEAE (Nightshade Family)
- Lycium berberioides
- Lycium texanum

STRACACEAE (Storax Family)
- Styrax youngae

VALERIANACEAE (Valerian Fam.)
- Valeriana texana

information source is: Kartesz, J.T., Biota of North America, Vol. I, International Conference for Outdoor Education, BONAC, Pittsburgh, Pennsylvania, 1977.

5.4.2 Fauna

Sixteen faunal species known to have occurred in Texas are Federally listed as endangered. One is listed as threatened (FR, Thurs., July 14, 1977, Part V). These species and their probability of occurrence in the McGregor area are shown in Table 5-8. The table is based on literature only and does not represent the results of site search. Much of the NWIRP-McGregor site is presently used for grazing cattle.

TABLE 5-8

FEDERALLY ENDANGERED AND THREATENED FAUNA - TEXAS

Species[a]	Likelihood of Occurring in Project Area
Texas blind salamander (*Typhlomolge rathbuni*)	No cave habitat
Fountain darter (*Etheostoma fonticola*)	No suitable stream habitat
Big Bend Gambusia (*Gambusia gaigei*)	Not reported in area and no suitable streams
Clear Creek Gambusia (*G. heterochir*)	Not reported in area and no suitable streams
Pecos Gambusia (*G. nobilis*)	Not reported in area and no suitable streams
Commanche Springs pupfish (*Cyprinodon elegans*)	Not reported in area and no suitable streams
Ivory-billed woodpecker (*Campephilus primeipalis*)	Restricted
Red-cockaded woodpecker (*Dendrocopos borealis*)	Not reported in area
Attwater's greater prairie chicken (*Tympanuchus cupida*)	Possible, but not reported in area
Southern bald eagle (*Haliaeetus leucocephalus leucocephalus*)	Possible transient
Mexican duck (*Anas diazi*)	Possible but area is north of usual range
Gray wolf (*Canis lupus monstrabilis*)	Project area east of reported range
Mexican wolf (*C. lupus baileyi*)	Project area north of reported range
Red wolf (*Canis rufus*)	Reports restricted to areas to east
Black-footed ferret (*Mustela nigripes*)	Unlikely; southernmost extension of range
Houston toad (*Bufo houstonensis*)	Not reported in area
American alligator (*Alligator mississippiensis*)	No suitable habitat

NOTES: [a] All species have "endangered status" except American alligator which has "threatened status".

6.0 ACTIVITY FINDINGS

6.1 INTRODUCTION

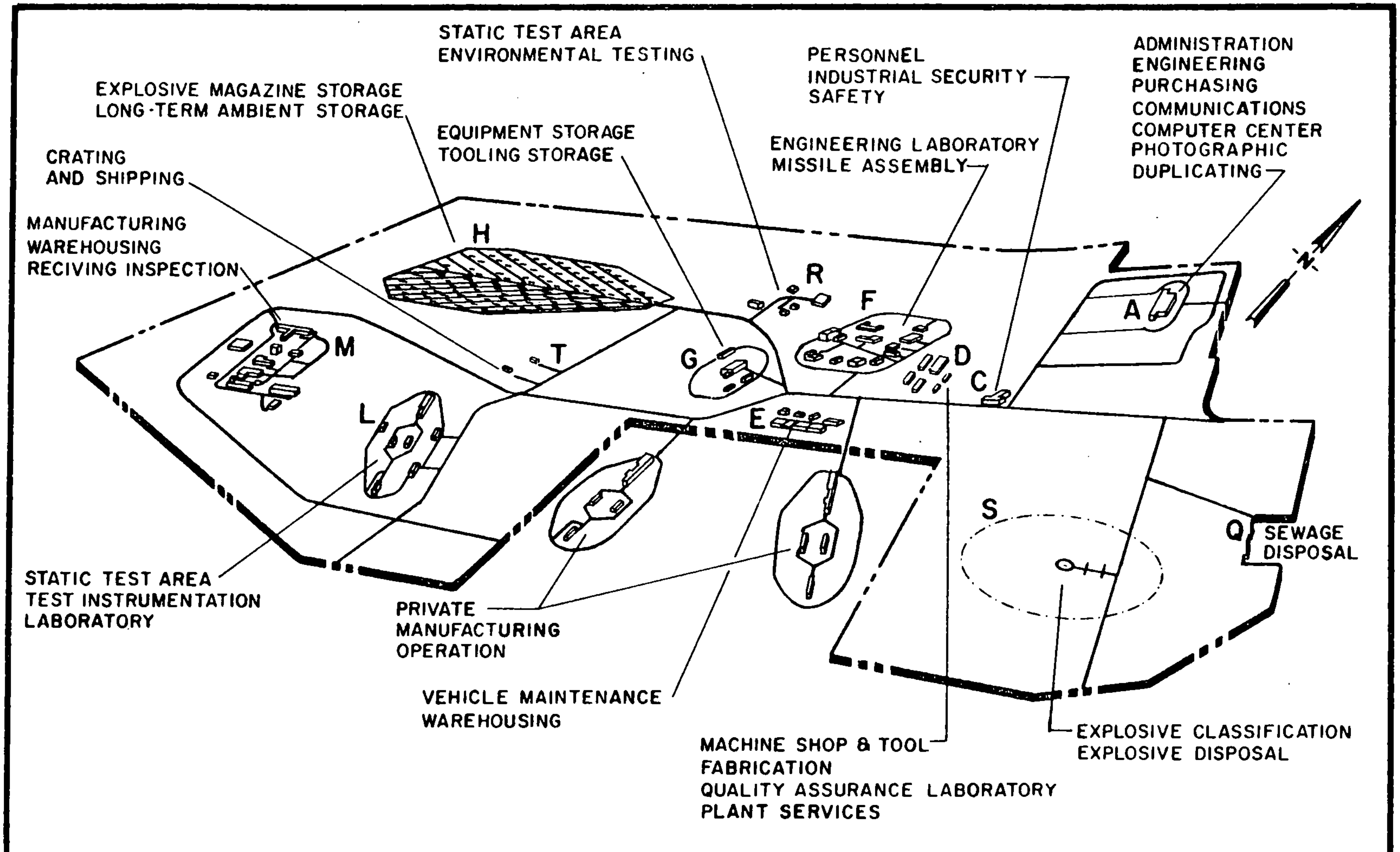
The NWIRP-McGregor facility was originally established during WWII as an assembly and bomb loading plant to support wartime efforts. The plant contained four load lines, now designated as Areas J,K,L and M. Chemical formulations were varied from 1942 through 1945, but the loads were generally TNT-based explosives. Plant activities also included a bomb booster line and an ammonium nitrate area. The booster line operation was housed in Area F. The high explosive, tetryl, was used in the booster assembly. Ammonium nitrate crystallization was performed in Area G. Area H was used for explosives storage facilities, and Area S was used for the burning of waste explosives.

The entire facility was disposed of after the war, and during the period immediately following the war, private manufacturing operations were conducted in various portions of the plant. Geigy Company, Incorporated, conducted pesticide blending activities in Area G. Area L was occupied by the Union Asbestos Company, which produced several sizes of asbestos pipe insulation.

The Air Force re-established a major portion of the facility as AF No.66 in 1952 for the production of ammonium nitrate based propellant boosters (JATO's). Some of the old buildings were rehabilitated and more were constructed. Initially, Phillips Petroleum Company operated the facility for the Air Force. Later, North American Aviation (which became Rockwell International) operated the facility, expanding into a wide variety of solid propulsion systems.

Hercules presently is the contractor/operator of the facility, now known as the Naval Weapon Industrial Reserve Plant (NWIRP). Current production capacity is more than 12 million pounds per year of composite propellants containing ammonium nitrate and another 12 million pounds of high-performance propellants containing ammonium perchlorate oxidizer. These facilities have been used over the years to produce rocket motors, intricate gas generators, igniters, and numerous other ordnance items. Approximately 150 buildings are now used for administrative and production operations. Major activities currently conducted in each of the designated areas are presented in Figure 6-1.

A number of non-ordnance activities have been conducted since the plant was constructed in 1942. Such operations as metal plating, painting and degreasing have always been an intregal part of the facility activities and have been primarily isolated in Area M. Electroplating operations are performed intermittently in Building M-1206. The plant houses a machine shop in Area D, and vehicle maintenance activities are performed in Area E.



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NWIRP - McGREGOR
AREA ACTIVITIES MAP

FIGURE 6-1

The NWIRP is equipped with two main boiler systems located in Areas F and M, the main production areas.

The NWIRP discharges domestic, cooling and industrial process wastewater at various locations throughout the site by means of septic tanks, an Imhoff tank and stabilization ponds, settling and evaporative ponds, and the city of McGregor sewage treatment plant. The sewer system, which once covered the entire facility, now serves only Areas A,B,C,D,F and R. Sanitary wastes from Area M are disposed of by the Imhoff system or by one of the two septic tank systems in the area. The other areas also use septic tanks for sanitary wastes.

All of the past and present activity findings including ordnance, non-ordnance, material storage, and waste disposal operations are presented in much greater detail in the pages which follow. These activities are summarized for each area of the facility. Figure 6-2 includes a legend for maps of the site's areas.

6.2 AREAS A, B, and C - ADMINISTRATION AND INDUSTRIAL SECURITY

The administration and engineering functions have always been located in the northeastern portion of the facility which has never contained ordnance activities. Figure 6-3 depicts the layout of the administrative area, now designated as Areas A,B and C.

During WW II, the Bluebonnet Administration group contained some 24 buildings. The individual buildings consisted of the Administration Building A-101, demolished in the late 1960's, Cafeteria, Hospital, Personnel Building, three H-shaped Dormitories (two for men and one for women), Telephone Exchange, 15 staff residences, and the headquarters building for the Fire and Guard Departments, Area C.

The Barracks and Trailer Park group, Area B, consisted of twelve temporary one-story barracks with three separate wash houses, a canteen, a residence for the manager of the trailer park and sixteen wash houses for the use of the occupants of the park which was constructed to accomodate 350 trailers.

Program management for Hercules activities is provided in centralized office facilities, Building A-100, to maintain communication and liaison with administrative, procurement, engineering, manufacturing, cost control, quality assurance, and program support functions. Prior to the construction of Building A-100 in 1965, the original Administration Building was used for administrative functions. Buildings A-101, 103 and 109 were all demolished in the late 1960's and Building A-103 was dismantled in the mid 1970's. The only other buildings now in use are Buildings A-105 and A-106, presently functioning as the telephone exchange and photographic lab, respectively.

Area B is located outside the present boundaries of the plant and is not currently in use. As previously mentioned, this area was used during WWII for temporary housing of Bluebonnet personnel.

124 BUILDING NUMBERS

EXISTING BUILDING

DEMOLISHED BUILDINGS

EXISTING COVERED WALKWAY

EXISTING ROADS

UNUSED ROADS

PONDS

BERMS OR BUNKERS

RAIL ROAD TRACKS

WATER LINES

SEWER LINES

FENCE LINE

SEPTIC TANK

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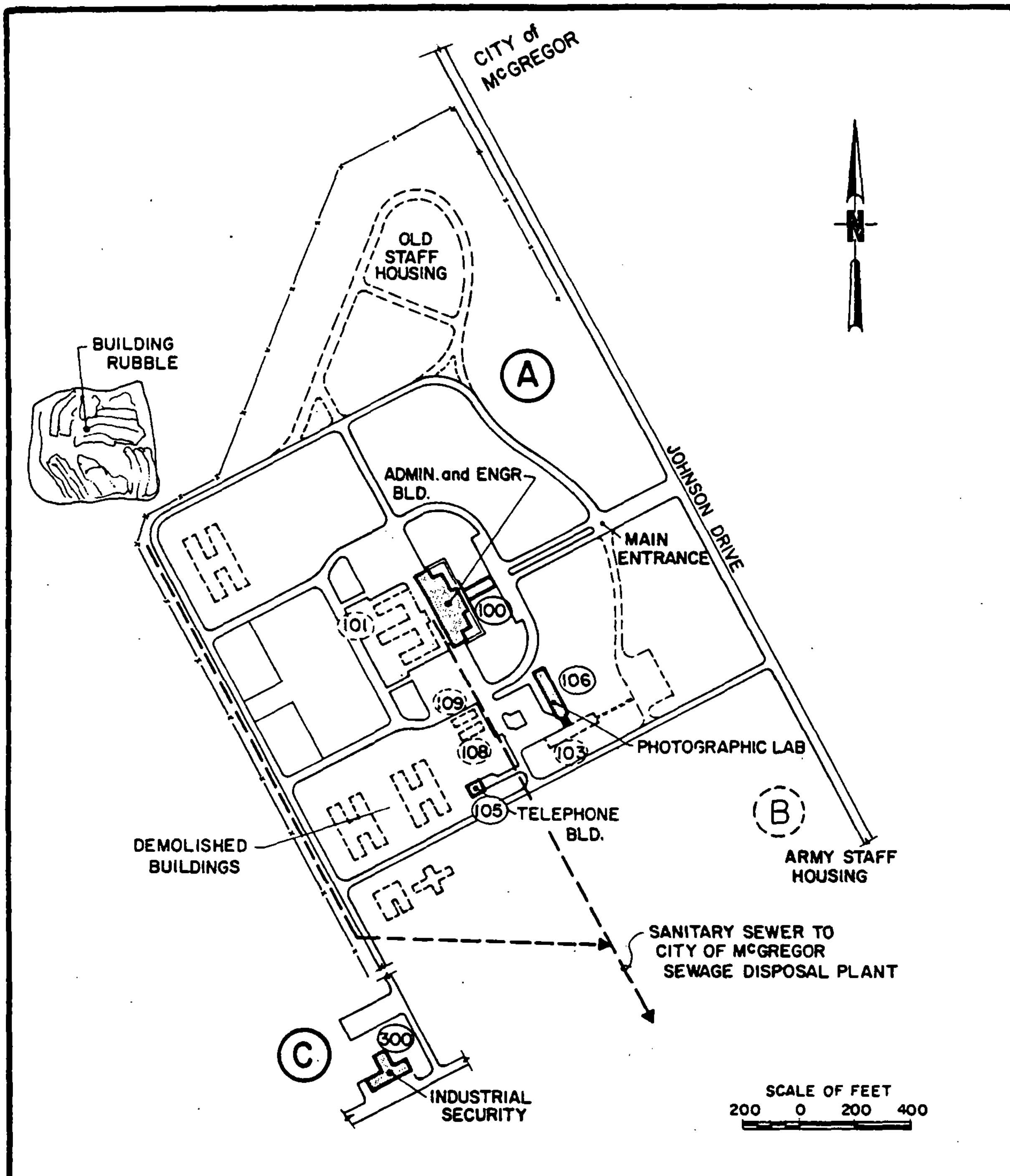
LEGEND
FOR AREAS A THRU Z

FIGURE 6-2



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AREAS A and C
ADMINISTRATION AND INDUSTRIAL SECURITY

FIGURE 6-3

The industrial security and safety functions have always been housed in Area C, Building C-300.

Service water for this area and all of the remaining areas is obtained from an on-site well water system established when the plant was originally built in 1942.

Since there are no production operations conducted in these areas, only sanitary wastewater is generated. This wastewater is discharged to the plant's sewer system as originally constructed and is treated at the city-operated sewage treatment plant located in Area Q.

A landfill, located just outside the northwest boundary of Area A, was sighted during the aerial reconnaissance conducted August 12, 1981. This disposal site appears to contain only rubble from the demolition of buildings within the area.

6.3 AREA D - MACHINE SHOP AND TOOL FABRICATION PLANT SERVICES

During the Bluebonnet era, this area was designated as the Shop and Warehouse group and contained the Chemical Laboratory, a Woodworking Shop, a Machine Shop, a General Warehouse and a Laundry. The area, when rehabilitated by the Air Force in 1952, was operated in a similiar manner.

Typical machine shop operations are now conducted in the area to support mission-oriented functions. The area, shown in Figure 6-4 is designated as Area D. Use of the railroad tracks located in this area and all tracks described in the other areas has been discontinued for some time. All buildings in this area, with the exception of Building D-418, are thought to have been constructed during WWII.

The principle operations presently conducted in the buildings of this area are listed in Table 6-1.

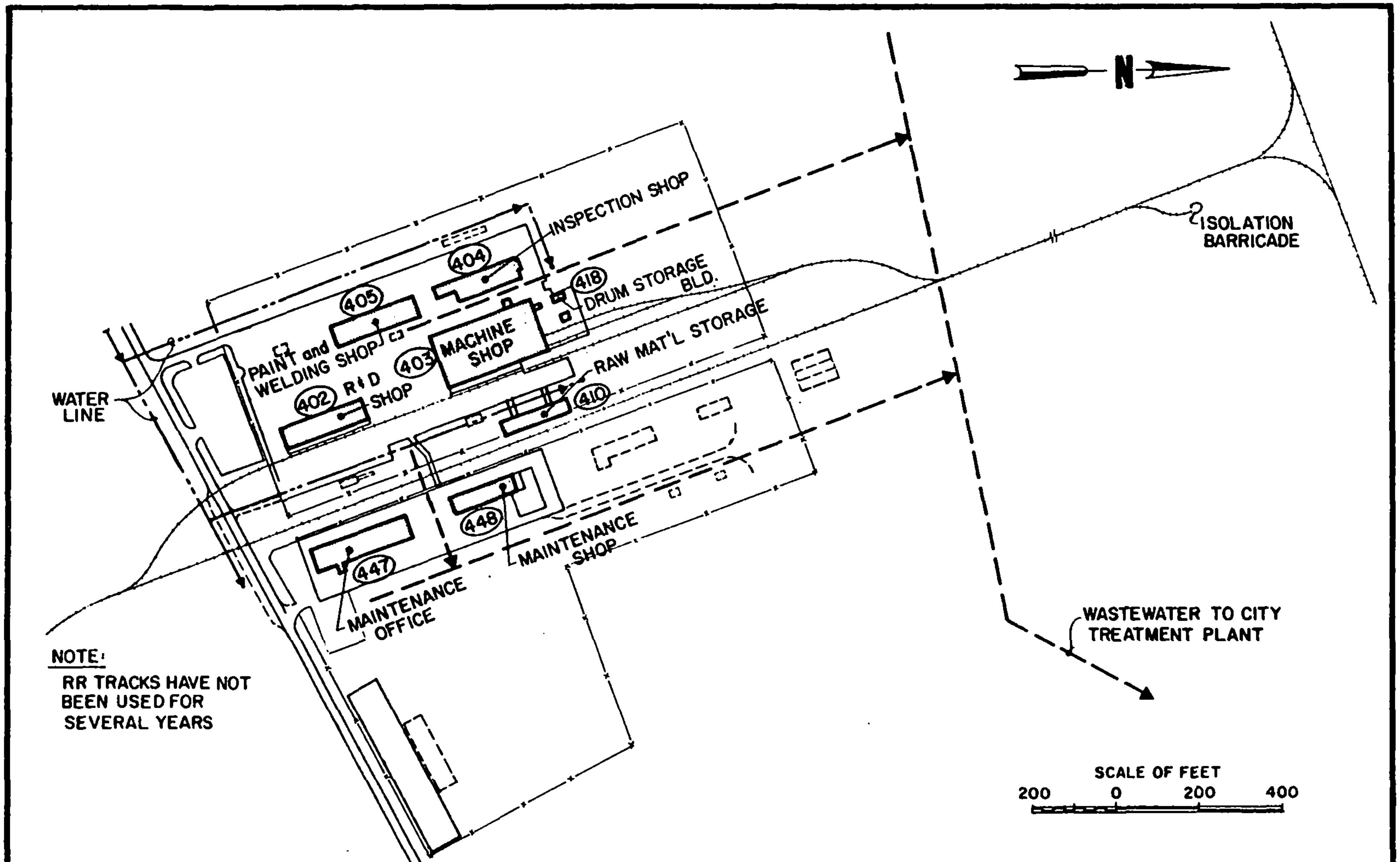
Small quantities of gasoline for supplying forklift trucks are stocked in above-ground portable steel tanks in the area. The tanks have a capacity of 500 gallons.

The paint spray booths used in Building D-405 have dry filters and should not present any wastewater contamination problems. All wastewater discharged from the area is treated at the city's treatment plant.

6.4 AREA E - RECEIVING, WAREHOUSING and VEHICLE MAINTENANCE

Area E was originally known as the Inert Storage group and contained a garage and three warehouses for storage of inert ingredients. The plot plan for the area is shown in Figure 6-5.

Formerly used as a shipping and receiving center for installation materials (1952-1970), Area E is presently used for storage of non-ordnance inert supplies. Activities carried out in this area are listed in Table 6-2.



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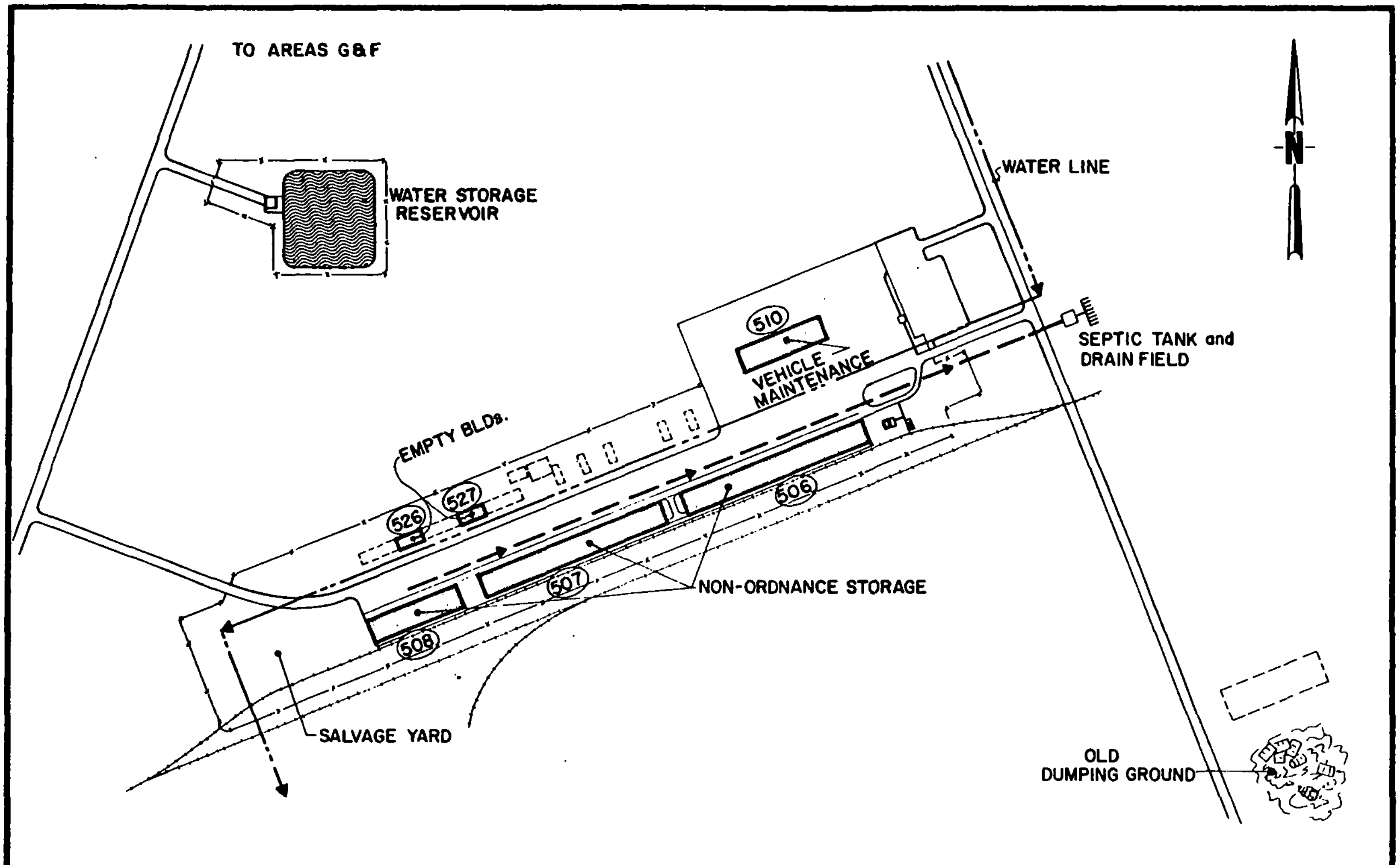
AREA D
MACHINE SHOP AND TOOL FABRICATION PLANT SERVICES

FIGURE 6-4

TABLE 6-1

SUMMARY OF AREA D BUILDINGS

Building Number	Building Description	Building Activity
D-402	Research and Development Shop	Used to store cutting oils
D-403	Production Machine Shop	Contains Stoddard and other miscellaneous solvents
D-404	Quality Assurance	Conduct bench scale laboratory tests
D-405	Tooling and Welding Shop	Contains paint spray booth and ovens
D-410	Raw Material Storage	No solvents
D-418	Drum Storage	Storage of 55-gallon drums of solvents and cutting oils
D-447	Maintenance Office	Store some cleaning solvents
D-448	Maintenance Shop	Typical shop operations



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SCALE OF FEET
150 0 150 300

AREA E
RECEIVING, WAREHOUSING AND VEHICLE MAINTENANCE

FIGURE 6-5

TABLE 6-2

SUMMARY OF AREA E BUILDINGS

Building No.	Description of Building	Activity of Building
E-506,507 and 508	Inert Storage	Tooling, extrusion and machining equipment
E-510	Vehicle Repair Garage	Gas storage
E-526 and 527		Not in use

NOTE: Underground gasoline and diesel storage tanks are located within the area.

Underground gasoline and diesel storage tanks are located within the area. The gasoline is stocked at Building E-510, in an above ground 1,000-gallon capacity steel tank and in a corrosion protected steel underground 10,000-gallon tank.

The storage facility does not generate much wastewater and is presently served by a septic tank located just to the east of the fenced area. This tract of land was originally served by the plant's main sewer system but was not rehabilitated in 1955. The sewer line from Area E was abandoned and plugged in 1970 after installation of the septic tank.

Scrap metal parts are piled in an area west of Building E-508 between scrap pickups. Pickups are conducted by a local salvage dealer. During the site survey in August, an open dumping site southeast of Area E was inspected and found to contain many 55-gallon drums; while the majority were empty, some containing silica sand from sand blasting operations conducted in Area M were found. Other materials present at this site included scraps of wood, wood shipping pallets and boxes, rubber tires and metal straps. Conversations with plant personnel indicate that the area has not been used for a dumping site since the early 1970's.

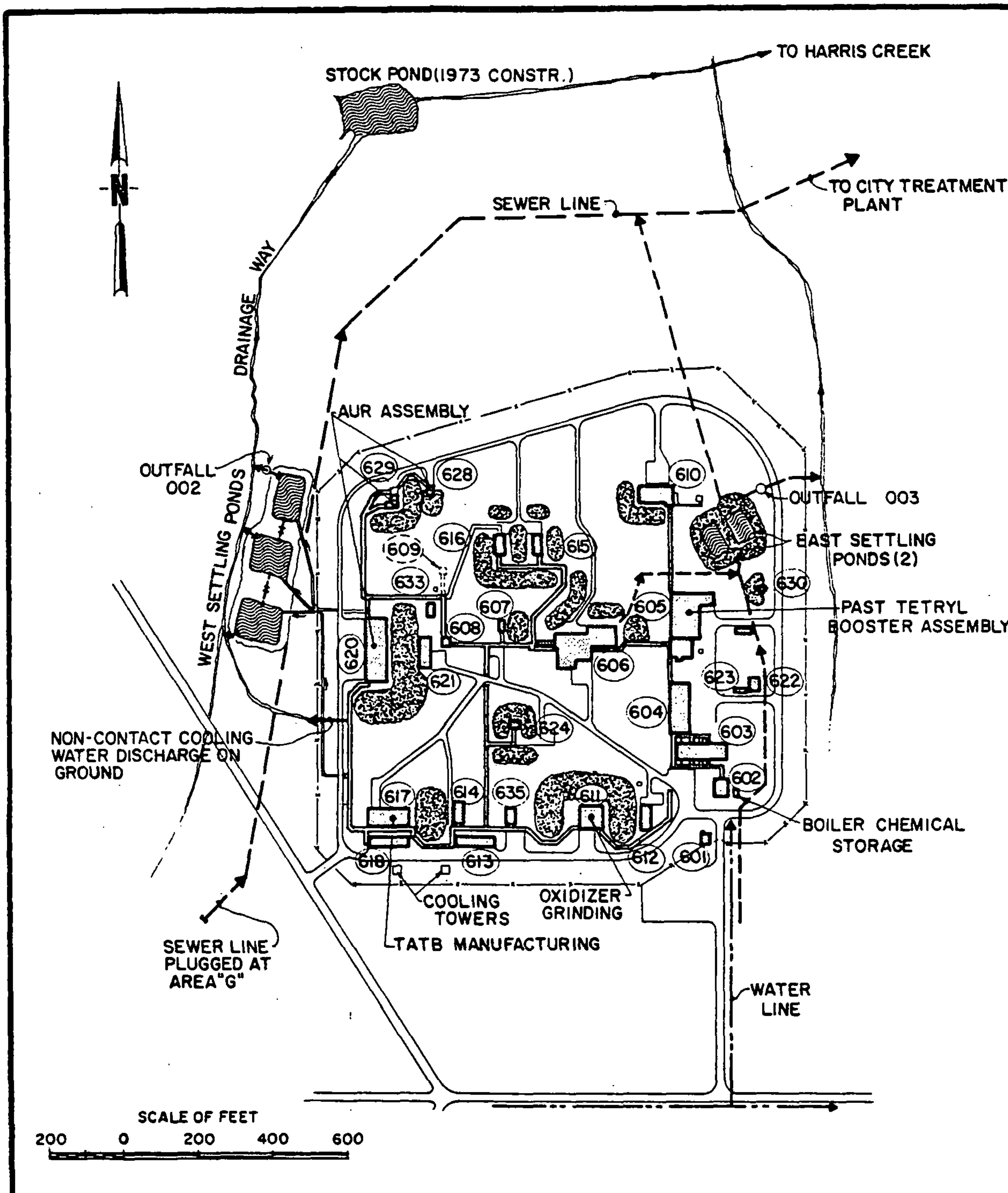
6.5 AREA F - ENGINEERING LABORATORIES and PILOT PRODUCTION

When Area F was built for the Army in 1942, only Buildings F-601 through F-610 existed. These buildings, designated the Bomb Booster Line, were used for the production of M-102 adaptor and M-104 auxiliary boosters. Tetryl was employed as the booster explosive. Additional buildings were constructed when the Air Force re-established the facility in 1952 for JATO boosters. Area F facilities now include All-up-Round (AUR) assembly, miscellaneous testing equipment and production of 1,3,5 triamino-2,4,6-trinitro benzene (TATB). The present building layout for the area, including the settling pond, is shown in Figure 6-6. A typical cross-section of the settling ponds are shown in Figure 2-1.

Area F now contains approximately 35 buildings which have been used for various production activities. Table 6-3 presents a brief summary of the operations conducted in each of the buildings since construction. The descriptions shown in parentheses are for Bluebonnet designations.

Some of the main pilot testing and pre-reproduction and manufacturing activities undertaken within the area are discussed below. These activities include: operations conducted in the Engineering Labs; AUR Assembly; TATB production; reinforced grain facilities; and, past booster operations using tetryl.

All buildings in Area F were designed to furnish adequate protection to personnel and equipment. Individual cells having remotely controlled processing equipment are used for hazardous operations, and earthen barricades are provided for many of the buildings. Enclosed ramps between buildings provide protection from natural elements and permit all-weather operations. Because of the relative hygroscopicity of many solid propellant ingredients and components, buildings where these materials are processed are humidity controlled to less than 50 grains of moisture per



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AREA F

ENGINEERING LABORATORIES AND PILOT PRODUCTION

FIGURE 6-6

TABLE 6-3

SUMMARY OF AREA F BUILDINGS

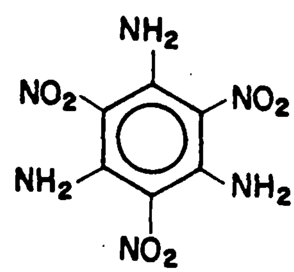
Building No.	Building Description	Building Activity
F-601	Maintenance Building (Timekeeper's Office)	Now used for insulation storage
F-602	Area Office (Line Office and First Aid Building)	-
F-603	Boiler Room (Change House and Power House)	Used as office space and change area
F-604	Chemical Storage (Inert Storage)	Formerly used for rubber molding and tooling
F-605	Propellant Formulation (Booster Assembly)	Now research and development laboratories
F-606	Advanced Rocket Area (Tetryl/Pelleting)	Now used for development of ducted rocket motors, until 1960 used for ignitor facility
F-607	Blended Tetryl Rest House	Cooling area for tetryl
F-608	Tetryl Screening and Blending	Now contains only fire extinguisher
F-609	Tetryl Service Magazine	Demolished
F-610	Engineering Laboratory Facilities (Booster Service Magazine)	Machining, tooling and test firing of 2 inch motors
(Post-War Construction)		
F-611	Oxidizer Grinding	Generates ammonium perchlorate waste which is bagged and burned
F-612	Equipment Room	Storage area
F-613	Lunch Room	Formerly used as control room for Building F-614
F-614	Storage Building	Used to support Building F-617 activities
F-615,616	Extruding	Presently empty, did contain a 40-ton rubber extruder
F-617	TATB Manufacturing	In mid-1960's used for reinforced grain propellant program (aluminum wire); late 1960s and 1970s not used for production activities
F-618	Equipment Area	Facilities support F-617 activities
F-619	-	Demolished previously
F-620,628 & 629	AUR Building	Assembly of all up round missle
F-621	Utility Room	Contains electrical equipment for F-620
F-622	Gas Storage	Bottle gas storage
F-623	-	Empty
F-624	X-Ray Building	Now empty, formerly used for case X-ray work
F-630	Explosive Aging Building	Long-term storage area
F-633	Janitor Storage	Storage of janitorial supplies
F-635	Drum Storage	Solvent storage for Building F-617 operations

pound of air.

The Engineering Laboratories, located in Buildings F-605 and F-610, are equipped for complete composite propellant research and characterization, as well as concurrent and corollary studies on liners, restrictors, and insulators. Research to determine the physical characteristics of visioelastic solid propellants and liners under actual rocket motor conditions is typical of activities currently conducted in the area. The lab also contains a flow visualization water table for subsonic/supersonic flow-field investigations. The smoke tunnel apparatus, used in connection with the water table, is basically an induced draft wind tunnel operated at low speed so smoke will remain visible. This visualization is primarily a tool for the investigation of flow physics. Other testing equipment includes: a direct-connect test structure and a portable exhaust plume characterization device.

AUR Missle Assembly is conducted in Building F-620. This building is divided into six cells, five of which are used for explosive handling and one cell designed to house the automatic test set-up for remotely controlled live testing. The building is designed for permissible loading of 20,000 pounds of Class 7 explosive. Wastewater generated from AUR operations discharges into an above-ground covered concrete flume gravity collection system, and then to the west settling ponds.

The pre-production manufacturing of TATB has been conducted in Building F-617 since late 1979. TATB is a secondary high energy explosive. The structural formula is as follows:



[TATB]

All the most commonly used nitroaromatic explosives contain three NO groups, generally in the 1,3,5 position. Aromatics are most often nitrated to the trinitro stage with mixed acid. The most commonly known and extensively used explosive is trinitrotoluene (TNT); however 1,3-diamino-2,4,6-trinitrobenzene (DATB) and TATB have found increasing application because of their low sensitivity to impact, shock and friction, and their exellent stability at elevated temperatures. The general properties of some of the explosives which have been prepared at NWIRP-McGregor are listed in Table 6-4.

TABLE 6-4

GENERAL EXPLOSIVE PROPERTIES

Compound	Name	Formula	Use	Melting Point (°C)	Molecular Weight	Color	Crystaline Form
1,3,5-triamino-2,4,6-trinitrobenzene	TATB	$C_6(NH_2)_3(NO_2)_3$	Secondary High Explosive	440	258	Yellow	Tri-clinic
2,4,6-trinitrotoluene	TNT	$C_7H_5(NO_2)_3$	Secondary High Explosive	80	227	Beige	Orthorhombic
Ammonium nitrate	AN	NH_4NO_3	Solid Oxidizer	170	80	White	-
Ammonium Perchlorate		NH_4ClO_4	Solid Oxidizer	-	117	-	-
Trinitrophenyl-methylnitramine	Tetryl	$C_7H_5N_5O_8$	Secondary explosive used as booster	130	287	Yellow	Monoclinic

The process also generates toluene bottoms which are disposed of at the burning ground in Area S.

The main source of TATB process wastewater is generated from washing activities. The wastewater effluent is discharged to the west settling ponds and may be very acidic and high in oxygen demand, dissolved and particulate solids, soluble nitrates and sulfates and contain some oil and grease. This wastestream could potentially contain toluene, ammonium chloride and residual TATB.

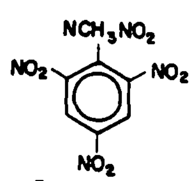
State-of-the-art technology was used during the mid 1960's for experiments conducted with reinforced grain propellants. These castable solid propellants were produced in Building F-617 for test use as rocket-propulsion fuel systems. The system derives its energy from chemical sources. Propellants are low explosives that carry their own oxidant or other reactant necessary to cause the planned reaction. The thrust of the escaping hot gases pushes the device forward.

The approximate composition of the reinforced grain propellant tested at NWIRP was as follows: ammonium perchlorate-70%, aluminum-16%, elastomeric polymer binder (polybutadiene, polyurethane, etc.)-14%. The difference in the formulation was the substitution of strong aluminum wire for the usual aluminum powder. Theoretically, if properly wound throughout the mass, the aluminum wire will be oxidized uniformly and supply the same heat as previously obtained from the powder. This concept was also used to strengthen the grain structure, thus improving the mechanical properties of the propellant. When properly wound, the aluminum wire takes the place of part of the container vessel for the propellant and yet burns away as the reaction proceeds. The overall effect is an efficient propellant with reduced container weight. Experimentation with this propellant was discontinued in the late 1960's.

From the later part of the 1960's until 1979 no production operations were conducted in this building. It was in 1979 that TATB production began.

Area F was originally used during WWII as the plant's Bomb Booster Line. Production activities of tetryl-based boosters were conducted in Buildings F-601-610. Most of the assembly operation was conducted in Building F-605. Tetryl pelleting was performed in Building F-606 and screening carried out in F-608.

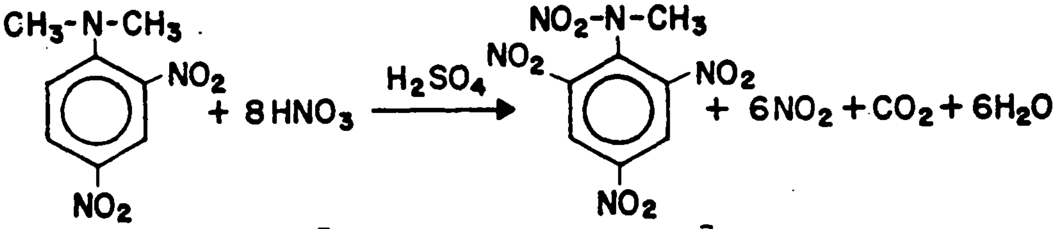
Tetryl [2,4,6 trinitrophenyl-methylnitramine $C_6H_2(NO_2)_3NCH_3NO_2$] was used at Bluebonnet in pressed form as the booster explosive because of its sensivity to initiation by primary explosives and its relatively high energy content. Tetryl, another aromatic nitro explosive, does not pose major industrial health hazards except during very high exposures. However, tetryl is highly irritating to the skin and mucous membranes and may cause severe upper respiratory tract irritation with coughing and epistaxis. It is highly stable, losing virtually no weight on prolonged storage at 80°C. The structural formula for tetryl is as follows:



[TETRYL]

If, in fact, actual batch processing of tetryl was conducted at Bluebonnet, it was probably prepared by the action of mixed sulfuric and nitric acid on dimethylanaline in a multiple-stage nitration:

$$C_6H_5N(CH_3)_2 + 2HNO_3 \xrightarrow{H_2SO_4} C_6H_3N(CH_3)_2 \cdot NO_2 \cdot NO_2 + 2H_2O$$



[TETRYL-NITRATION]

Dimethylaniline is dissolved in an excess of concentrated sulfuric acid (3 or 4 to 1) at 20-30°C to give dimethylaniline sulfate. The mixture is nitrated with mixed acid (67% nitric/16% sulfuric), first to 2,4-dinitrodimethylaniline at about 100°C, and finally to tetryl. The crude product is then filtered, washed repeatedly with water, dissolved in acetone, and recovered by evaporation of the acetone and filtration.

The main source of wastewater generated during tetryl processing is from the washing step. Data is inconclusive concerning the extent of wastewater discharge from tetryl operations at the NWIRP-McGregor. Wastewater may have been discharged to the natural drainage way along the east side of Area F.

A number of materials and processing chemicals are stored in and around Area F buildings. These include: fuel oil; toluene; ammonium perchlorate; sulfuric acid; sodium hydroxide; and acetone. Building F-603 is equipped with two 44.75 MBTU gas fired boilers capable of burning #2 fuel oil.

Fuel oil is stocked for firing the steam boilers when there is a curtailment of natural gas. There is an above ground, diked, 25,000-gallon tank just to the east of Building F-603. The tank is valved off, except when the boilers are being fired on fuel oil. The diked area is constructed of top soil which is composed of an impervious high-plasticity inorganic clay. The dikes are protected from erosion by limestone rip-rap.

There are four above-ground steel tanks adjacent to Building F-617 used to store toluene necessary for TATB production. One tank has a capacity of 7,000 gallons, one has 2,000 gallons and two have capacities of 3,000 gallons. The tanks are clustered inside a concrete containment area with a volume of 9,900 gallons. The recovery area is equipped with a drain for drainage of accumulated rain water.

Ammonium perchlorate is received in dry granular form in 250 pound drums. After processing at Building F-611, approximately 4000 lb are poured into a tote-bin and transported to one of the two 300-gallon propellant mixers in Area M.

Boilers housed in Building F-603 require boiler water conditioning prior to use. The sulfuric acid used to condition the well water for use in the boilers is stored in a tank outside the building. The acid is contained in an above-ground, diked, 3,500-gallon tank. The dike is protected from erosion with limestone rip-rap, which also serves as a neutralizer for the acid in the event of a spill. Sodium hydroxide is also used in boiler water conditioning. This material is received in solid form in 400 pound drums.

There was some indication that the acetone required in the production of tetryl was stored outside Building F-604 on the concrete pad.

The area was originally served by the plant's sewer system. The quantity and disposition of the process related wastewater generated at that time is unknown. But, all of Area F sanitary wastewater is now discharged to the sewer system and treated at the city disposal plant. A partial plot plan is presented in Figure 6-7 depicting the configuration of both east and west settling ponds used to treat process-related waste streams since the early 1950s.

Two settling ponds (east ponds) are located in the northeast portion of Area F as shown on the partial plot plan. Floor drains from Buildings F-605, 606 and 610 discharge to these ponds through a system of covered concrete flumes from the three operating buildings located in the vicinity. This treatment system was constructed in the mid 1950's for the prupose of receiving waters from building equipment wash down, overflow from wet-type dust collectors and miscellaneous non-contact heating and cooling water. These waste streams may have contained small quantities of ammonium nitrate and perchlorate.

The purpose of the system has not changed, but in the early 1970's, most of the operations were shut-down. Since that time, there has been only minimal amounts of wastewater discharge to the east ponds with no known discharge out of the system. This wastewater consists primarily of small quantities of wastewater discharge from the laboratory and chemical formulation buildings. The ponds ultimately overflow into a drainage ditch (Outfall 003) located along the east side of the area and flow northerly to a tributary of Harris Creek, which flows into the South Bosque River.

Three ponds, designated as the west settling ponds, are located immediately west of Area F just outside the boundary fence. Wastewater generated in Buildings F-611, 614, 617 and 620 discharges to these ponds through a system of covered concrete flumes. The treatment system was built in the early to mid 1950's for those buildings located in the south and west portions of the area. Waste streams from building and equipment washdown, overflow and miscellaneous contact water are discharged to the ponds. Non-contact cooling water, once discharged to the ponds, has been diverted to a separate surface discharge just south of the pond network. The ponds were originally operated in parallel but have now been reworked to operate in series from south to north. The second pond contains two air lines for wastewater aeration.

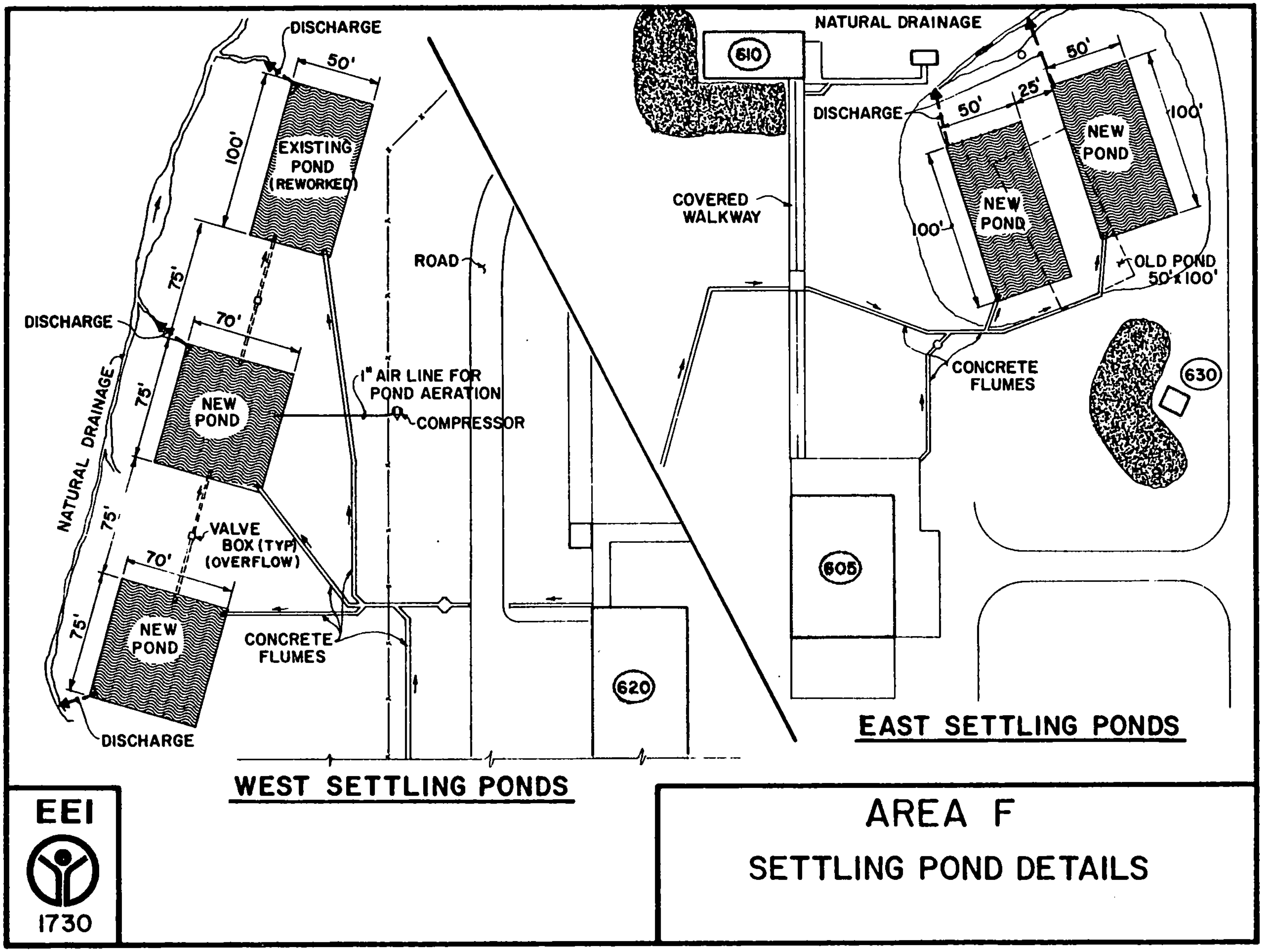

DISCHARGE
50'
100'
EXISTING POND (REWORKED)
75'
DISCHARGE
70'
NATURAL DRAINAGE
75'
NEW POND
1" AIR LINE FOR POND AERATION
COMPRESSOR
ROAD
75'
VALVE BOX (TYP) (OVERFLOW)
70'
75'
NEW POND
CONCRETE FLUMES
DISCHARGE
620
WEST SETTLING PONDS
NATURAL DRAINAGE
610
DISCHARGE
50'
50'
25'
100'
NEW POND
100'
NEW POND
COVERED WALKWAY
OLD POND 50'x100'
CONCRETE FLUMES
630
605
EAST SETTLING PONDS
EEI
1730
AREA F
SETTLING POND DETAILS

FIGURE 6-7

Washdown and dust collector wastestreams could potentially contain small quantities of ammonium nitrate and ammonium perchlorate, which are fire hazards when dry but will not burn when wet or after long exposure to water. In addition, trace quantities of TATB, TCTNB and TCB, may be present in Building F-617 washdown wastewaters generated in TATB production operations. The majority of this wastewater consists of product/process washwater. The batch discharge from the three-pond system is approximately 20,000 gallons per day.

The pond discharge, called Outfall 002, flows into a normally dry drainage ditch which passes through a stock pond north of the area to a tributary of Harris Creek. Harris Creek, in turn, flows into the South Bosque River, which joins the North and Middle Rivers at Lake Waco and ultimately flows into the Brazos River Basin.

6.6 AREA G - TOOLING AND EQUIPMENT STORAGE

Area G, depicted in Figure 6-8, was originally constructed during WWII and was called the Ammonium Nitrate (AN) Area. The AN crystallizing line contained six units, each capable of producing some 93,000lbs. of AN per day. After the war, Geigy Company conducted pesticide blending operations in the area (primarily in Building G-705). Phillips took over in the early 1950's, and since then the area has only been used for equipment storage.

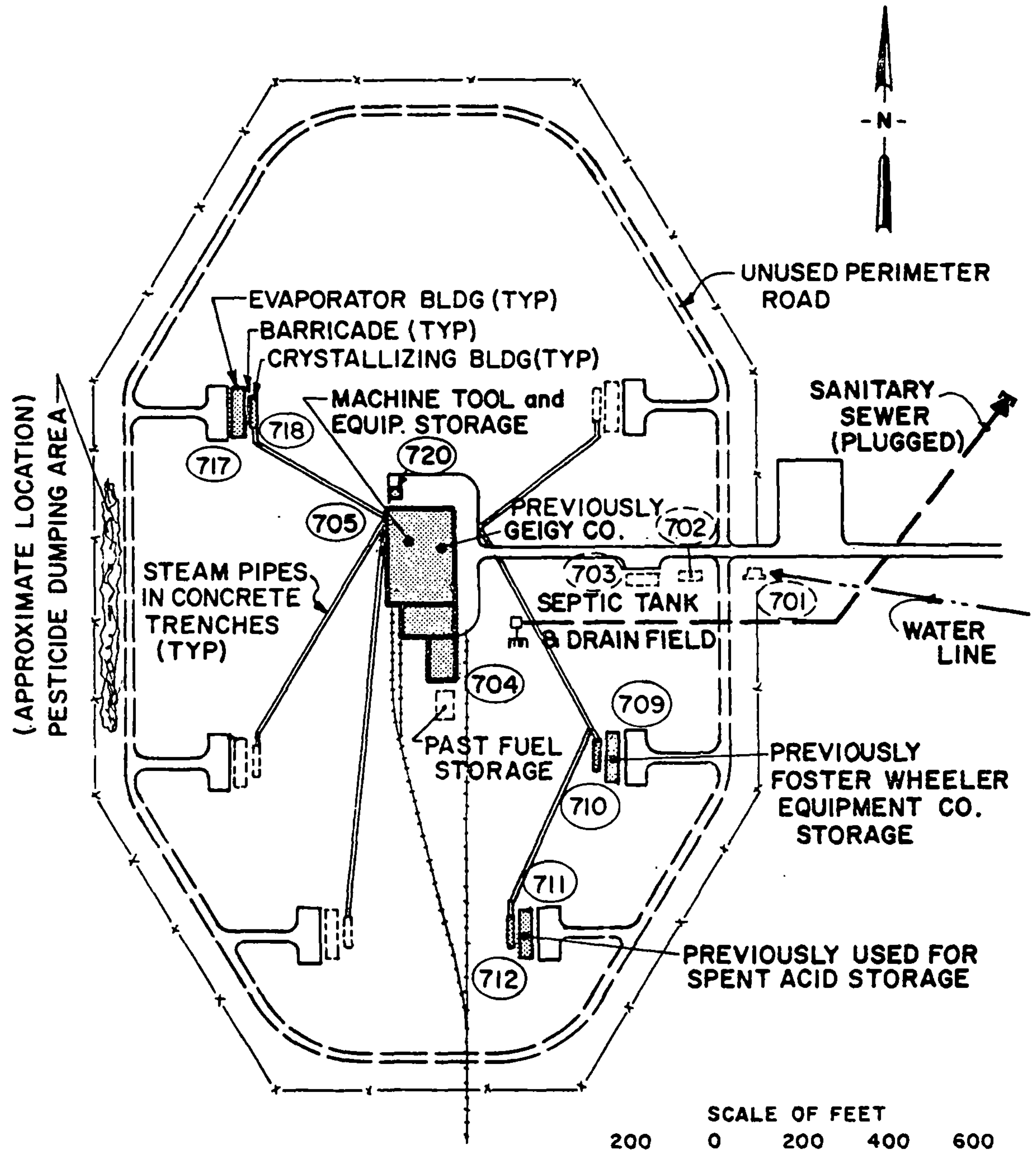
A summary of past and present building activities is presented in Table 6-5.

The AN operations were initiated on December 7, 1942. The plant was constructed with six units, each containing an evaporator and crystallizing building, which allowed two units to supply each of the three load lines under full production.

Ammonium nitrate, NH_4NO_3, is a white crystalline solid. It is highly soluable in water, 187 grams per 100 grams of water at 20°C.

The commercial processes for the manufacture of AN depend almost entirely on the neutralization of nitric acid with ammonia in liquid or gaseous form. Various procedures may be followed in producing ammonium nitrate in dry, usable form, but essentially three steps are involved: neutralization, evaporation of the neutralized solution, and control of the particle size and characteristics of the dry product.

Batch graining was employed at Bluebonnet during the war. This method involved the batch neutralization of aqueous nitric acid with by-product ammonia liquor, evaporation of the solution, and graining during the last stages of drying. The graining process primarily involved manual control of the operation. This technique produced an average of approximately 3 million pounds per month of grained AN while in service. Toward the end of WWII the facility was used to produce fertilizer grade AN.



EEI 1730

AREA G
TOOLING AND EQUIPMENT STORAGE

FIGURE 6-8

TABLE 6-5

SUMMARY OF AREA G BUILDINGS

Building Number	Building Description[a]	Building Activity
G-701	Timekeepers Office	Demolished sometime after World War II
G-702	Line Office/First Aid	Demolished sometime after World War II
G-703	Change House	Demolished sometime after World War II
G-704	Boiler House	Storage building
G-705	Tank and Bulk Storage	After World War II, Geigy operations, later tooling and equipment storage
G-707,709, 711,713, 715,717	Evaporator Buildings	G-709 - Foster Wheeler for short period; G-711 - Spent acid storage until November 1980
G-708,710, 712,714, 716	Crystallizing Buildings	Not used after World War II, some demolished

NOTE: [a] Bluebonnet facilities

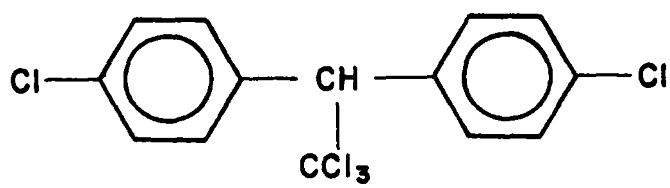
After WWII Building G-705 was used by the Geigy Company. Geigy operations included mixing and blending of technical grade pesticide raw materials such as benzene hexachloride, DDT, toxaphene and sulfur into final form for use on crops. A majority of the pesticide product formulations were made in dry form for aerial spraying of cotton. Geigy 3-5-40 cotton dust was formulated as follows:

Active Ingredients	Composition
a) Gamma isomer of benzene hexachloride	3%
b) Other isomers of benzene hexachloride	17%
c) Dichloro-diphenyl-trichloroethane (DDT)	5%
(DDT-setting point 90°C min.)	
d) Sulfur (Not less than 93% through [illegible] mesh [illegible])	40%
Inert Ingredients	35%
TOTAL	100%

A soil contamination survey was conducted in May 197[illegible] by SOUTHDIV to determine the suitability of the area for agricultural outleasing. During the study, 28 soil samples were collected in and around Area G. Ten of these samples were collected in the disposal area located on the western edge of the area just inside the boundary fence. Surface sample results indicated high concentrations of several pesticides including DDT, toxaphene, and sulfur within the disposal area. Lesser concentrations of DDT were evident elsewhere.

Pesticides, specifically insecticides, are agents or preparations for destroying insects and are frequently classified according to their method of action. Stomach poisons are lethal only to insects that ingest them; contact insecticides kill following external bodily contact; and fumigants act on insects through their respiratory systems.

DDT, 1,1,1 trichloro-2,2 -bis(p-chlorophenyl)ethane, was first synthesized in 1874 and is one of the most widely known insecticides. The structural formula of this insecticide is as follows:

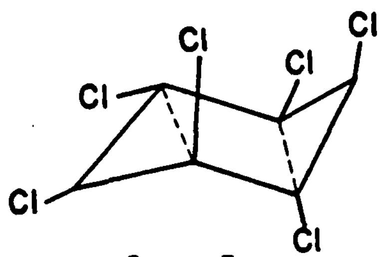


[DDT]

Technical DDT is a white amorphous powder, composed of up to 14 chemical compounds.

DDT is the most permanent and durable of the commonly used contact insecticides because of its insolubility in water, its very low vapor pressure and its resistance to destruction by light and oxidation. These characteristics generated shortcomings. A ban in 1974 resulted from the discovery that slow degradation of DDT allows it to be stored in the fat of living organisms and, thus it builds up in the natural food chain.

Geigy's cotton dust also contained BHC (or benzene hexachloride) which has the following structural formula:

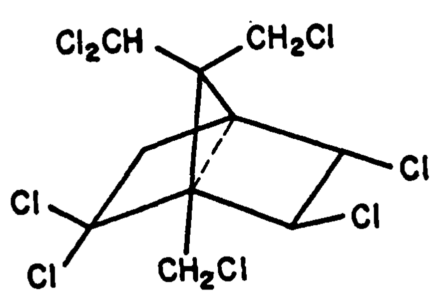


[BHC]

This compound exists in a number of stereoisomers, the gamma isomer being by far the most toxic. BHC is prepared by the chlorination of benzene in the presence of sunlight: $C_6H_6 + 3Cl_2 \rightarrow C_6H_6Cl_6$. The crude product is a grayish or brownish amorphous solid with a characteristic odor; it begins to melt at 65°C. Widely used to control the boll weevil in cotton, BHC, unless purified, is generally unsuitable for food crops because of its strong musty odor.

Toxaphene, another component found at the site, is an important chlorinated camphene insecticide which kills all common cotton pests. Toxaphene has the approximate empirical formula $C_{10}H_{10}Cl_8$.

The most active ingredients in technical toxaphene are 2,2,5-endo-6-exo-8,9,10-heptachlorobornane and 2,2,5-endo-6-exo-8,9,10-octachlorobornane, which has the following structural formula:



[TOXAPHENE]

Toxaphene is extremely toxic to fish with lethal concentration (LC) values to trout and blue gill of 0.003-0.006ppm. Toxaphene also is highly toxic to birds. Its soil persistence has been difficult to assess because of the complex mixture, but estimates for half-life range from 2 months to 10 years.

Storage of Foster-Wheeler/Leavy construction equipment in Building G-709 was the only other activity known to have occurred within the area during the post-war years. Since the early to mid 1950's the area has only been used for facility contractor tooling equipment storage.

The extent of wastewater discharge from the AN operations is unknown but the plant's sewer system served the area. The sewer was plugged in the 1960's, and sanitary needs are now served by a septic tank located east of Building 705.

6.7 AREA H - STORAGE MAGAZINES

This area is located in the northwestern part of the site and contains 118 Richmond-type storage magazines. The layout of the buildings is shown in Figure 6-9. These rather small "igloo" type structures, used for storing explosive components, were constructed with three concrete walls, one wooden wall and a roof of laminated gypsum board.

Area H, originally called the High Explosive Storage Area, is presently used for inert storage of rocket motors, moth-balled tooling equipment, off-spec materials, and AUR guidance systems. The igloos are assigned building numbers in the 800's with even-numbered buildings to the north and odd-numbered structures to the south.

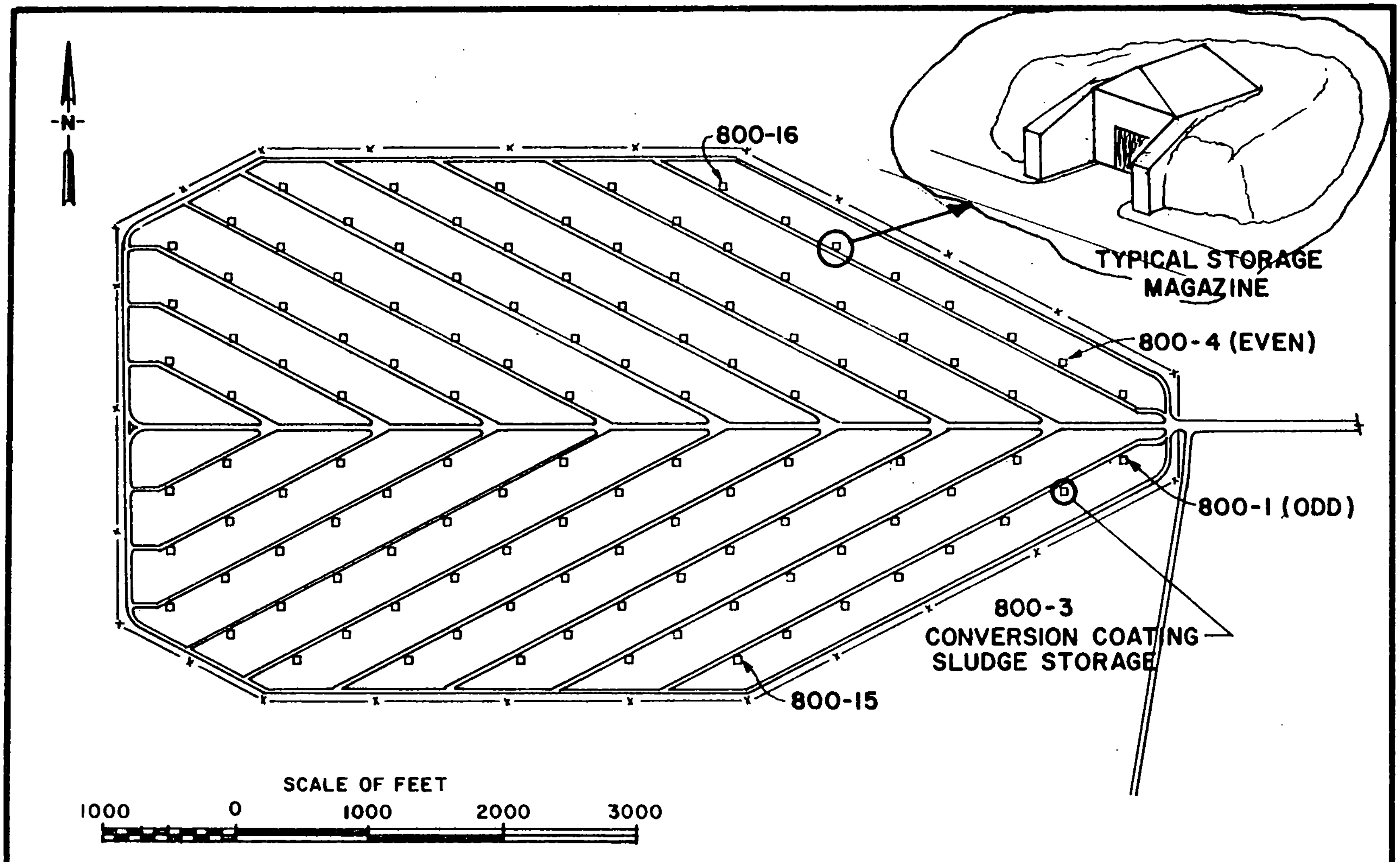
Building H-800-3 is being used for the storage of hazardous waste sludge generated from chemical conversion coating operations in Area M. This operation is scheduled to shut down in October, 1981 and, at that time all drums will be hauled to a hazardous waste disposal site.

No water and sewer service has ever been available to this area, nor have there ever been railroad facilities within the tract.

6.8 AREA J and K - PRIVATE MANUFACTURING OPERATIONS

Initially constructed as Bomb Load Lines #1 and #2, these areas (J and K, respectively) are now owned and operated by private manufacturing concerns. Area J is presumably owned by MKP Industries, formerly Eisen Brothers, and contains several mobile home operations and a van conversion company. These company names are Perm-A-Dwell Corp., Kinder Manufacturing Company, and Companion Van Inc.

Area K is apparently now owned by Winston Industries and, formerly, by McAx Corporation. This area is occupied by two companies, McGregor Homes and Del Brook Homes.



EEI
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AREA H
STORAGE MAGAZINES

FIGURE 6-9

The layout of both load lines was identical when originally constructed by the Army in 1942. A typical layout for the lines is depicted in Figure 6-10 along with building discriptions. Production operations began on Bomb Load Lines #1 and #2 on October 16 and November 27, 1942, respectively.

The lines were originally designed to produce 1000# S.A.P. Bombs, AN-M59, but due to shortages of bomb bodies, some 1000# G.P. Bombs AN-M30 were loaded on Line #2. These bombs were loaded with amatol, a mixture of AN and TNT. Line #1 started loading bombs with straight TNT on May 10 and Line #2 on May 17, 1943. In the third quarter of 1943, Line #1 changed over to the production of 105mm Howitzer shells and Line 2 began producing AN-M4 Cluster bombs. In June 1944, Load Line #1 was again converted, this time to make various fragmentation bombs. In January of 1945, loading of 1000# S.A.P. bombs was resumed on Line #1 and in February, Line #2 started loading 500# G.P. bombs with tritonal, a 20-80 mixture of powdered aluminum and TNT. Production on both lines was discontinued on August 14, 1945 due to V-J day.

Some wastewater was generated from load line operations. There were some problems encountered at this plant concerning the elimination of TNT contamination of the discharge water from the load line wash pits. The wash pit is designated as Facility No.11 on Figure 6-10.

Various methods were studied for eliminating the TNT which was carried with this wastewater, such as discharging the waste stream over beds of activated carbon, discharge of the wastewater to the plant's sanitary sewer system, and others. The activated carbon method was eliminated due to excessive cost. The discharge of this contaminated water into the sanitary sewers and the treatment plant did not remove the TNT from the wastewater in any appreciable quantity.

It was finally decided that the best method would be to impound this wastewater in long ditches, permitting it to seep through the ground and find its way into the natural water courses.

Areas J and K were originally served by the plant's sanitary sewer system. Sewer lines from the areas were plugged some years ago, and the areas are now serviced by septic tank systems.

6.9 AREA L - STATIC TESTING

Static test firing facilities are now housed in the area once called Bomb Load Line #3. The layout of this area is depicted in Figure 6-11.

Operations conducted in this area during WWII were similiar to those of Lines #1 & #2, Areas J and K, respectively. Initially, the line produced 100# G.P. Bombs. In March of 1943 this line began producing 1000# Semi-Armor-Piercing (S.A.P.) Bombs. The line continued 1000# S.A.P. Bomb production until May of 1943 when it was shut-down. Toward the end of 1943 the line was re-opened to produce M2 TNT Demolition Blocks. This line operated on demolition blocks until about the middle of May 1944. The line was then turned over to the engineering department for retooling and remodeling to make 500# G.P., M64A1, Composition "B" bombs, a 75

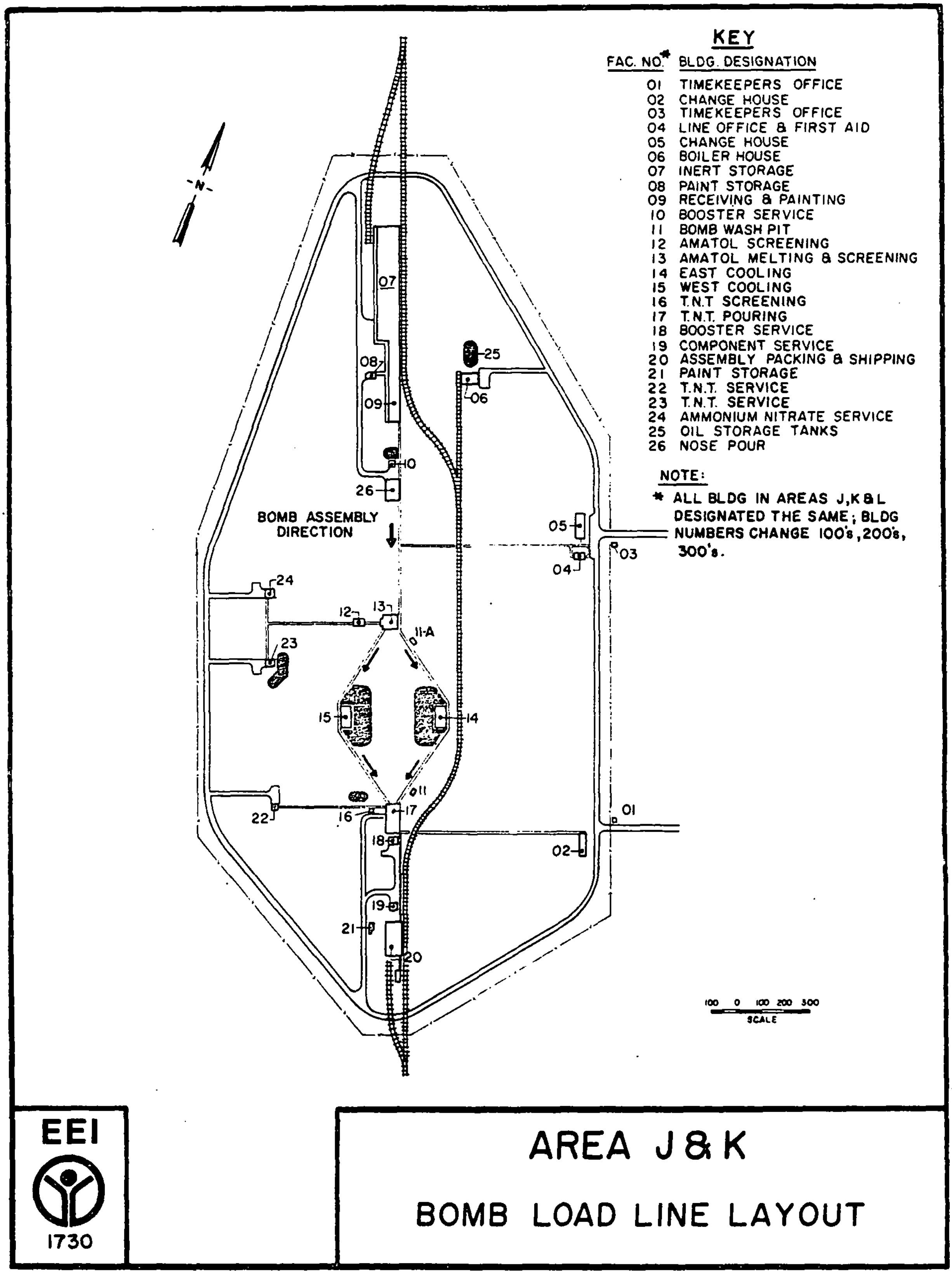
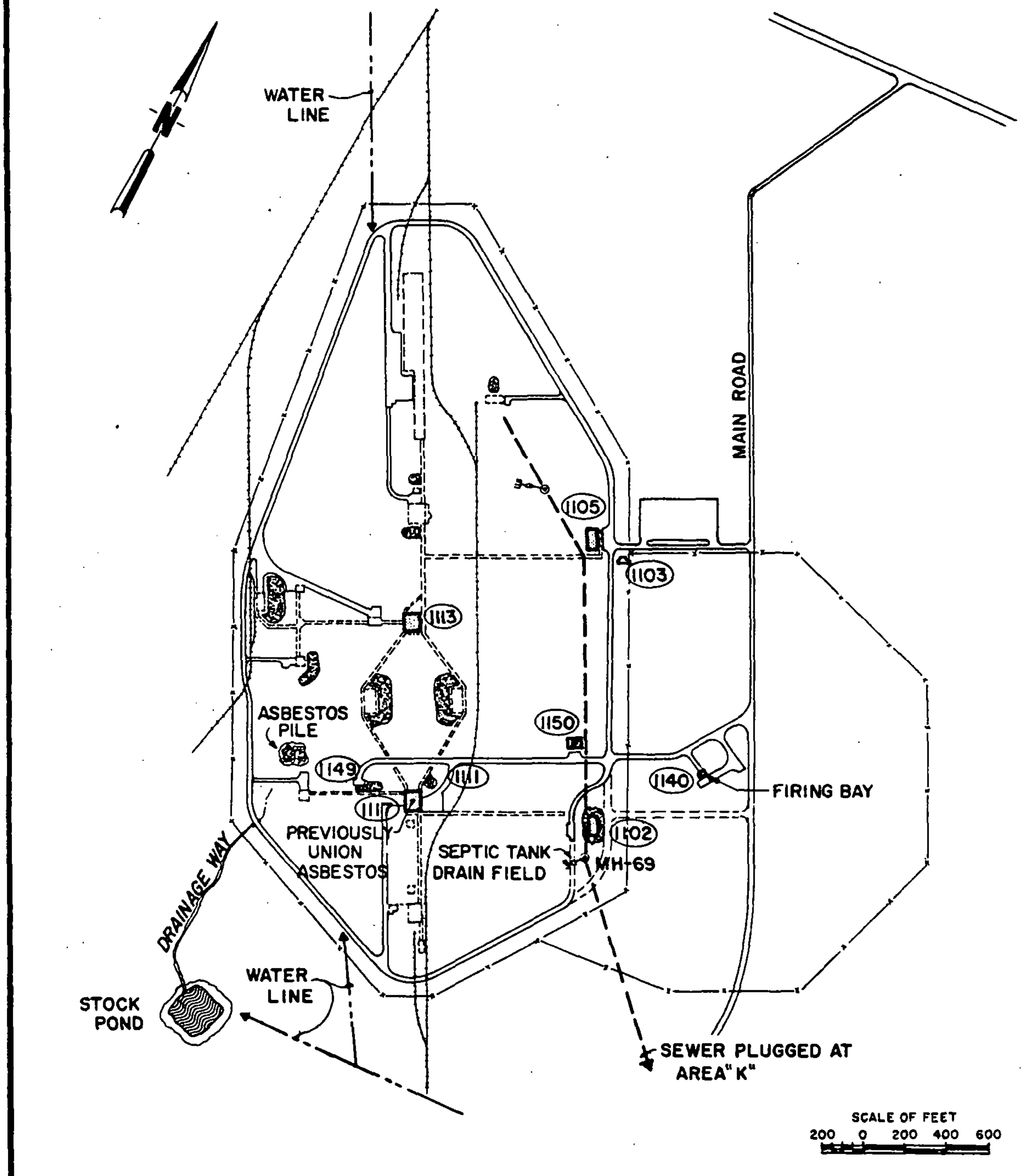

KEY
FAC. NO.* BLDG. DESIGNATION
01 TIMEKEEPERS OFFICE
02 CHANGE HOUSE
03 TIMEKEEPERS OFFICE
04 LINE OFFICE & FIRST AID
05 CHANGE HOUSE
06 BOILER HOUSE
07 INERT STORAGE
08 PAINT STORAGE
09 RECEIVING & PAINTING
10 BOOSTER SERVICE
11 BOMB WASH PIT
12 AMATOL SCREENING
13 AMATOL MELTING & SCREENING
14 EAST COOLING
15 WEST COOLING
16 T.N.T SCREENING
17 T.N.T. POURING
18 BOOSTER SERVICE
19 COMPONENT SERVICE
20 ASSEMBLY PACKING & SHIPPING
21 PAINT STORAGE
22 T.N.T. SERVICE
23 T.N.T. SERVICE
24 AMMONIUM NITRATE SERVICE
25 OIL STORAGE TANKS
26 NOSE POUR
NOTE:
* ALL BLDG IN AREAS J,K & L DESIGNATED THE SAME; BLDG NUMBERS CHANGE 100's, 200's, 300's.
N
BOMB ASSEMBLY DIRECTION
11-A
100 0 100 200 300
SCALE
EEI
1730
AREA J & K
BOMB LOAD LINE LAYOUT

FIGURE 6-10



EEI
1730

AREA L
STATIC TEST

FIGURE 6-11

percent/25 percent mixture of TNT/RDX. Production of 500# G.P. bombs continued until March of 1945 when preparations were made to load some 2000# S.A.P. bombs with Picratol, a 52-48 mixture of ammonium picrate and TNT. The line was finally closed in June 1945.

During the period following the war and prior to Air Force rehabilitation, Union Asbestos Company manufactured several sizes of pipe insulation in the area. A block flow diagram of the asbestos production building is presented in Figure 6-12. An approximately 1 acre pile of disposed asbestos fibers is still present in the western portion of the area.

Asbestos is a generic term describing a wide variety of naturally formed, hydrated silicates that, upon mechanical processing, separate into mineral fibers. There are two fundamental varieties of asbestos: serpentine, and amphiboles.

Asbestos fibers are unique minerals combining unusual physical and chemical properties which make them useful in the manufacture of a wide variety of residential and industrial products. Of mineral origin, asbestos does not burn, does not rot, and, dependent on variety, possesses extremely high tensile strength as well as resistance to acids, bases, and heat. Similarly, when processed into long, thin fibers, asbestos is sufficiently soft and flexible to be woven into fire resistant fibers.

The inhalation of excessive quantities of free asbestos fibers over prolonged periods of time can increase the risk of developing certain diseases of the lung within 20 or 30 years. The three diseases associated with the inhalation of asbestos are: asbestosis, anonmalignant fibrotic lung condition; bronchogenic (lung) carcinoma: and mesothelioma, a rare cancer of the lining of the chest or abdominal cavities.

Reduction of asbestos dust exposure is at present the only known method of preventing disease among workmen. When dust levels are low, risk to employees and incidence of disease drops sharply.

Only a few of the old Bluebonnet bomb line buildings of this area are still standing. Facilities presently occupying the area are listed in Table 6-6.

No data is available on the types and quantities of process wastewater generated during the Bluebonnet era. However, there was supposedly a wash pit near the building designated L-1211. The area was served by the plant's sewer systems though. Several septic tank systems were installed in the mid 1960's to serve sanitary requirements for the office areas being used.

6.10 AREA M - Manufacturing

Production activities are now centered in the western portion of the facility, designated as Area M, shown in Figure 6-13. Two basic types of propellants are manufactured: (1) AN composites, and (2) ammonium

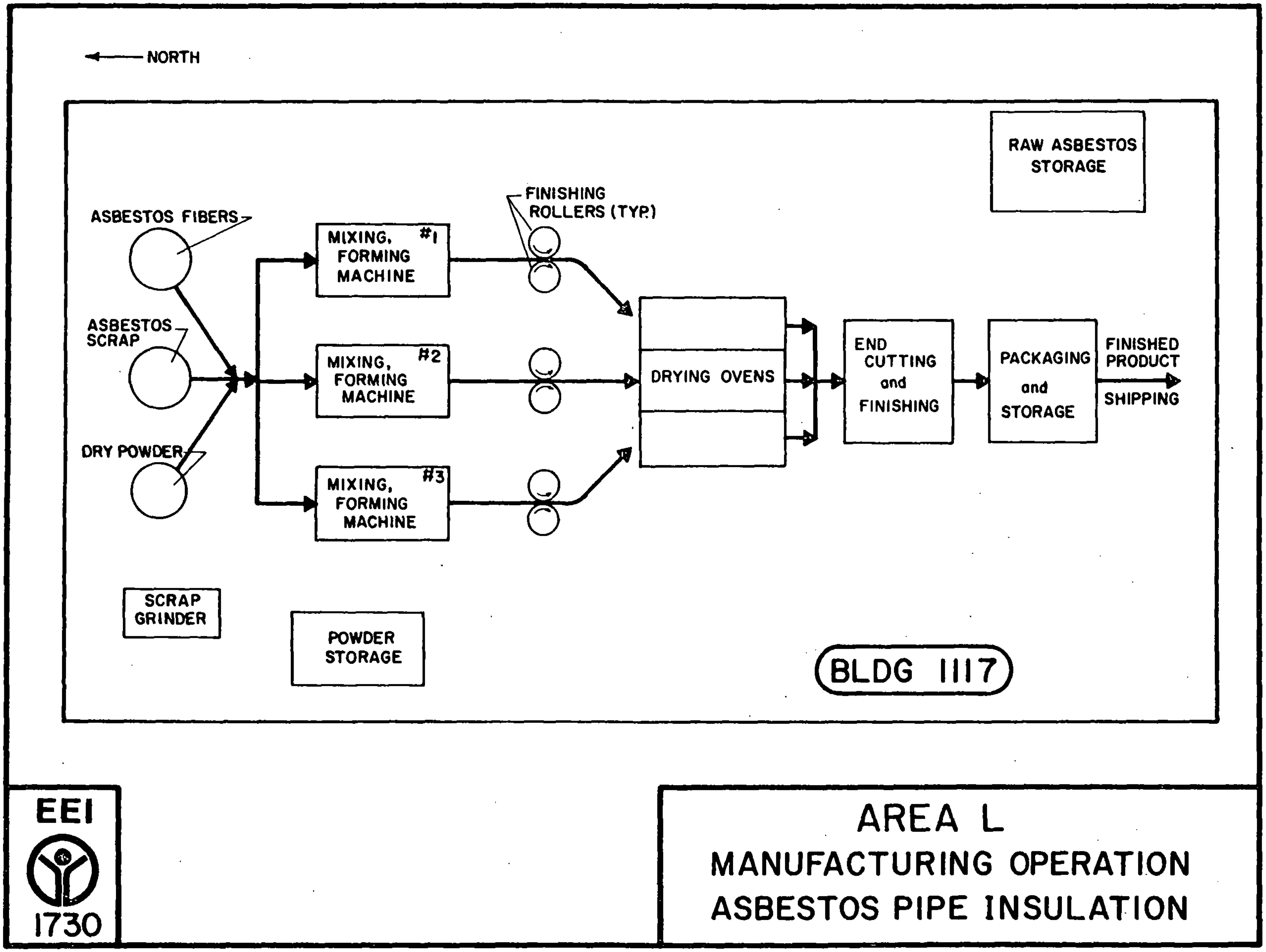

NORTH
RAW ASBESTOS STORAGE
ASBESTOS FIBERS
ASBESTOS SCRAP
DRY POWDER
MIXING, FORMING MACHINE #1
MIXING, FORMING MACHINE #2
MIXING, FORMING MACHINE #3
FINISHING ROLLERS (TYP.)
DRYING OVENS
END CUTTING and FINISHING
PACKAGING and STORAGE
FINISHED PRODUCT
SHIPPING
SCRAP GRINDER
POWDER STORAGE
BLDG 1117
EEI
1730
AREA L
MANUFACTURING OPERATION
ASBESTOS PIPE INSULATION

FIGURE 6-12

TABLE 6-6

SUMMARY OF AREA L BUILDINGS

Building Number	Building Description	Building Activity
L-1102	Test Control Room	Control for L-1140
L-1103	Guard House	Torn down
L-1105	Test Area Office	Offices, instrumentation laboratory and shop
L-1111	Control Room	Control for L-1149, presently empty
L-1117	Test Equipment Storage	Storage since AF No. 66, Union Asbestos during post war years, during Bluebonnet was TNT pour building
L-1140	Firing Bay	Contains test firing hold down equipment
L-1149	Firing Bay	Used until mid-1960s
L-1150	Conditioning Boxes	Contains hot and cold test boxes for motors

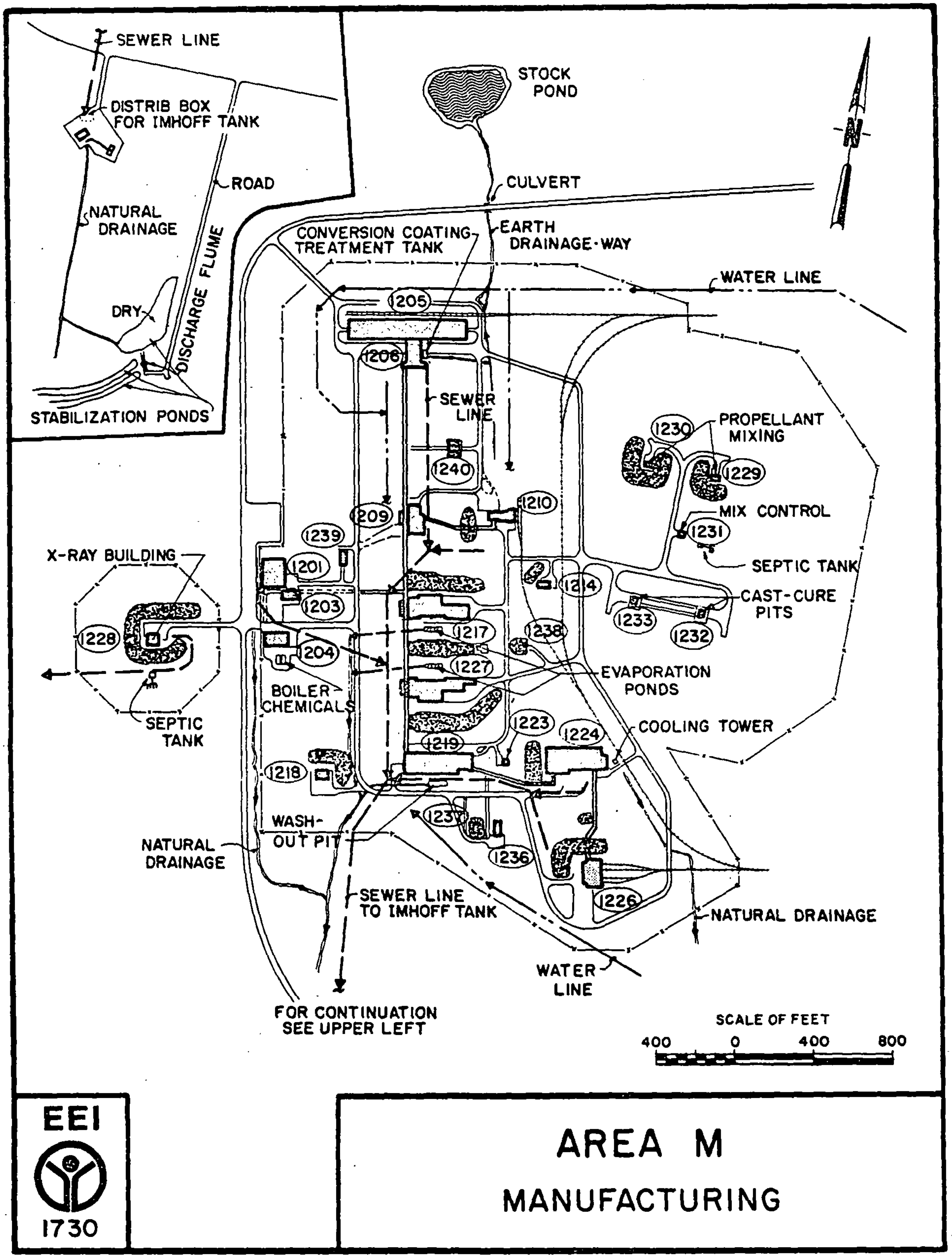

SEWER LINE
DISTRIB BOX FOR IMHOFF TANK
ROAD
NATURAL DRAINAGE
DRY
DISCHARGE FLUME
STABILIZATION PONDS
STOCK POND
CULVERT
CONVERSION COATING TREATMENT TANK
EARTH DRAINAGE-WAY
WATER LINE
1205
1206
SEWER LINE
1240
1209
1210
1230
PROPELLANT MIXING
1229
MIX CONTROL
1231
SEPTIC TANK
1239
1201
X-RAY BUILDING
1203
1214
CAST-CURE PITS
1233
1232
1228
1217
1238
1204
1227
EVAPORATION PONDS
BOILER CHEMICALS
SEPTIC TANK
1223
1224
COOLING TOWER
1219
1218
WASH-OUT PIT
1237
1236
NATURAL DRAINAGE
1226
SEWER LINE TO IMHOFF TANK
NATURAL DRAINAGE
WATER LINE
FOR CONTINUATION SEE UPPER LEFT
SCALE OF FEET
400 0 400 800
EEI
1730
AREA M
MANUFACTURING

FIGURE 6-13

perchlorate oxidized composites. The area was originally constructed in late 1944 because of the increased demand for bombs during the war. At that time the area was known as Bomb Load Line #4. The line was designed to load 60,000-500lb. TNT bombs per month. Production activities got underway in February 1945.

The layout of this line was quite different from that of the other lines in the plant. The Inert Storage Building, now Building M-1205, was set perpendicular to the main axis of the line to provide convenient and efficient unloading and handling space for all inert materials. A long straight covered ramp extended from this building through the Paint Building, the Melt Pour Building (M-1209) and both Cooling Buildings (M-1217 & 1227) to the Tail Pour Building (M-1219). This ramp extended through the barricades between the explosive buildings in concrete tunnels. The Tail Pour Building included second and third floors with melt units and Dopp Kettle equipment. The Shipping Building contained four car-loading spots under cover as well as a shop for preparation of dunnage. The offices, cafeteria and change house were all in one large tile building, M-1201. The Melt Pour Building was equipped with four Dopp Kettles to give the line much greater capacity.

On February 19, 1945 Load Line #4 started loading 500# G.P. bombs with Tritonal, a 20-80 mixture of powdered aluminum and TNT. During the month of February, 60,000 bombs were produced, meeting the design capacity. In the months which followed, the design capacity was routinely exceeded.

Since the war, the area has been used exclusively to manufacture various types of rocket motors. The two basic oxidizers for composite propellants manufactured are AN and ammonium perchlorate. Processing capacity is 12 million pounds per year of each of the two types. Propellant processing buildings are humidity controlled to less than 50 grains of moisture per pound of air. Hazardous mixing operations are conducted by remotely controlled equipment, and earthern barricades are provided where necessary for protection.

A summary of the individual building activities are presented in Table 6-7. Each of the buildings is listed numerically and contains a brief explanation of the major operation contained in the building.

Ammonium perchlorate processing is conducted in several buildings. Initially, oxidizer is ground, graded, and weighed in Building F-611, which has a capability of grinding 8,000 pounds per 8-hour shift. Propellant is mixed in Building M-1229 and/or M-1230; each building contains a 300-gallon Baker Perkins mixer. These mixers are remotely controlled from Building M-1231. The small and medium sized rocket motors are cast in Building M-1217 and cured in Buildings M-1219 and M-1224. Propellants are trimmed in Building M-1237, and motors are assembled in Building M-1224.

The second propellant, AN, is processed in a series of buildings similiar to ammonium perchlorate. Oxidizer is dried, ground, and weighed in Building F-611, which has a capacity of grinding approximately 14,000 pounds of AN per shift. The propellant is mixed, blocked, and extruded in

TABLE 6-7

SUMMARY OF AREA M BUILDINGS

Building No.	Building Description	Building Activity
M-1201	Office Area	Contains restrooms and shower facilities
M-1203	Lunch Room	Cafeteria
M-1204	Power Plant	Area boiler plant
M-1205	Inert Storage	Warehouse, shipping and receiving; environmental control area in center, case insulation
M-1206	Electroplating Area	Chemical conversion coating tanks, paint spray booth, TCE degreasing
M-1209,1210	Insulation Facilities	Deactivated at present, in 1960s used for rubber case insulation activities
M-1214	Mixing Area	Contains 300-gallon mixing bowls; scrap, waste solvent to burning ground
M-1217	Propellant Casting-Ammonium Perchlorate	Poured from 380-gallon mix tank, three cells used for casting, insulate some cases, contaminated solvent to burning ground
M-1218	Cure Oven	Presently not in operation
M-1219	High Pressure Washout	20,000 psi water jet for rinsing out reject motors, low volume of wastewater
M-1223	Storage Area	Not presently used, formerly solvent storage
M-1224	Final Motor Tooling	Paint booth, igniters
M-1226	Product Shipping Area	Crating, packaging
M-1227	Propellant Casting-Ammonium Nitrate	Assembly of small igniters, 25-gallon mix tanks, dry cleanup of materials, blocking press to consolidate propellant
M-1228	X-Ray Building-13 MEV LINAC	Constructed mid-1960s, septic tank, film processing, silver recovery operation
M-1229,1230	Mixer Buildings	Mix propellants, vertical tanks, dry cleanup, disposed of at burning ground
M-1231	Control Room	Built mid-1960s, remote control equipment for Buildings M-1229 and M-1230
M-1232,1233	Cast-Cure Pits	Ultra fine ammonium perchlorate, dust to burning grounds
M-1236	Propellant Machining	Remotely controlled operation
M-1237	Control Room	Control equipment for M-1236
M-1238	Storage Bunker	Not used since World War II
M-1239	Temperature Control	Age rocket motors
M-1240	Sand Blasting	Not presently in use

Building M-1227, which contains a mixing and forming line designed specifically for this phase of manufacture. Five 100-gallon Baker Perkins mixers are located in the building. A large, hot-air oven in Building M-1219 is used for nitrate propellant cure, while motors may be assembled in either Building M-1227 or M-1224. Dry clean up techniques are employed in the processing areas. The scrap material is disposed of at the burning ground.

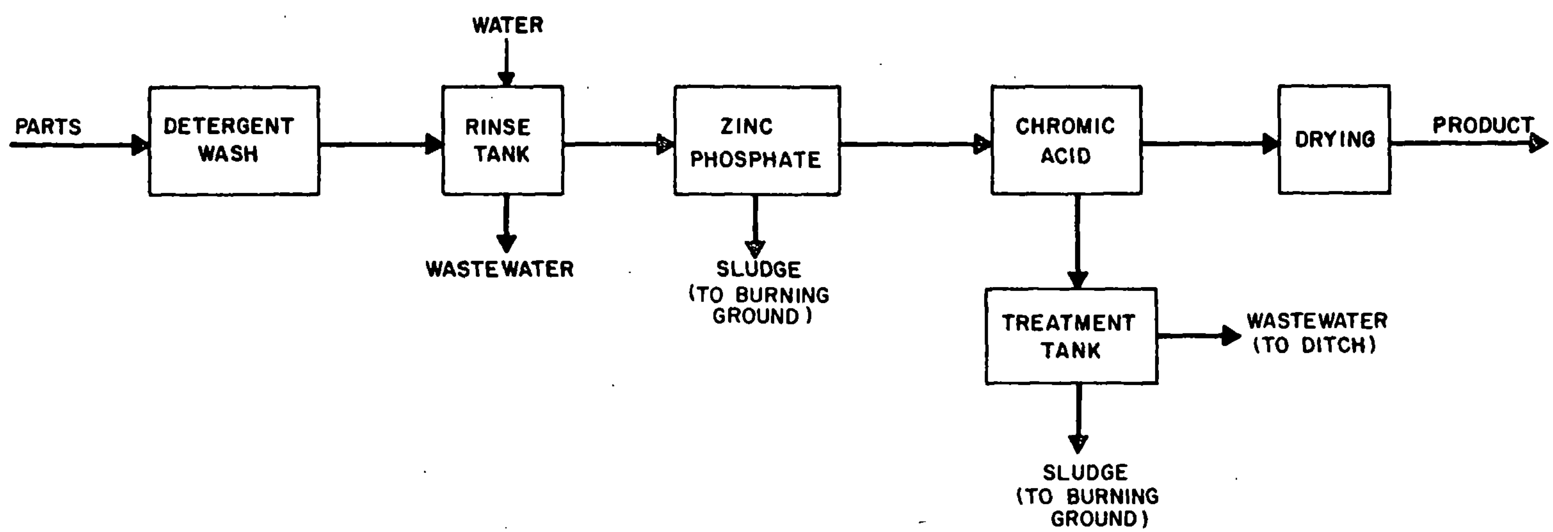
Only limited quantities of wastewater are generated from propellant processing activities located in Buildings M-1217 and M-1227. The wastewater is discharged into two small evaporation ponds located between the buildings.

In the hardware preparation area, Building M-1206, various activities include treatment and coating of metal parts. During the period 1954 through 1958 phosphate treatment of motor cases was conducted. A block flow diagram of this process is shown in Figure 6-14. Wastewater from the rinse tanks was discharged directly to the ditch toward the north pond. Present operations require the use of a conversion coating process. This process is illustrated in Figure 6-15. Plating solutions are discharged to a treatment tank located just outside the building. Again, rinse water overflow is discharged to the ditch.

The spent process baths flow to the treatment tank where the hexavalent chromium is reduced to the trivalent state with sodium bisulfide in an acid solution. The solution is then neutralized with calcium hydroxide. This action produces an insoluable calcium sulfate precipitate which is disposed of by an outside contractor. The neutralized solution is then discharged to the surface drainage way flowing toward the pond north of Area M. The occasional quantities of wastewater produced by the Passivation process using nitric acid and sodium dichromate are discharged without treatment to the ditch.

The case washout operation located in Building M-1219 utilizes a high pressure water stream, approximately 20,000 psi, to cut out ammonium perchlorate propellant from reject rocket motors. Motor cases and hardware can then be recovered for reuse. The washed material flows into a concrete flume containing a burlap bag for the solids. Potential pollutants include asbestos, ammonium perchlorate and unreacted binder ingredients such as methyl azindinyl phosphine oxide (MAPO) and various epoxides. Wastewater then flows to a small evaporation pond located to the south of Building M-1219. Effluent from the pond overflows into a storm drain running toward the south.

The other major activity conducted in the area is nondestructive testing of motors in Building M-1228. This building houses a 13-MEV LINAC and a GE 1000-KV X-ray machine. The LINAC is capable of penetrating 100 inches of propellant and can handle motors up to 14 feet in diameter. No radioactive materials are kept in this area, only electromagnetic type machines are used. A silver recovery unit is used in the building to treat film developing fluids. This building discharges wastewater into a drainage ditch which flows south into Station Creek.



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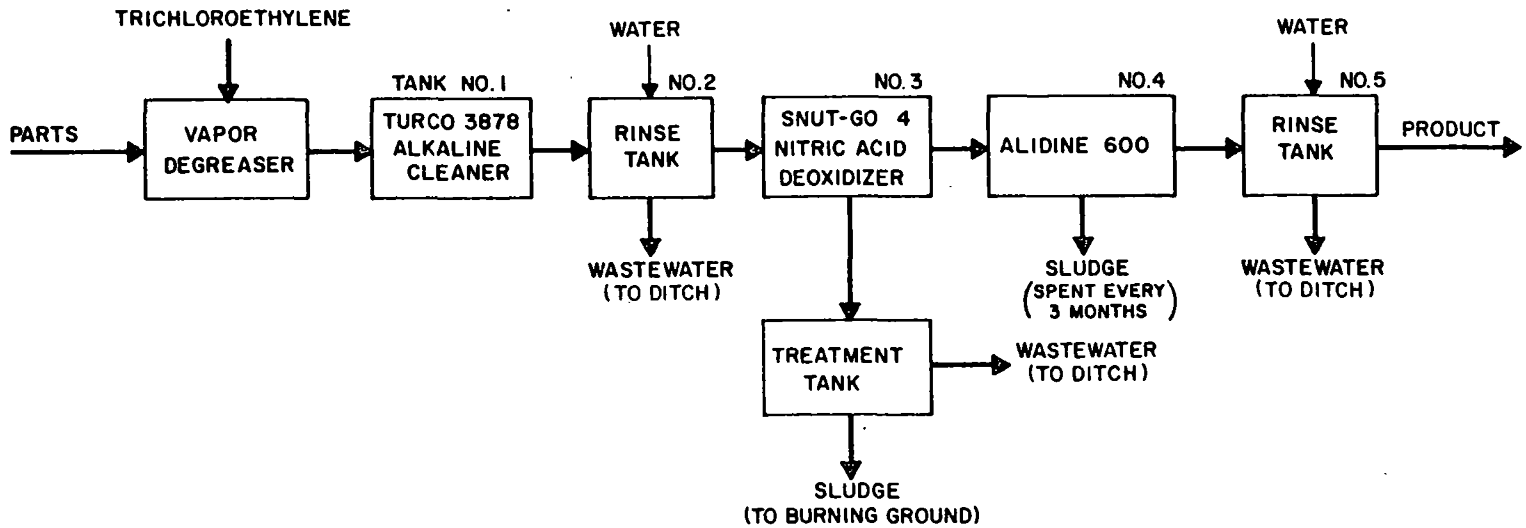
NWIRP-McGREGOR

ZINC PHOSPHATE PROCESS

FIGURE 6-14



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NWIRP - McGREGOR
CONVERSION COATING PROCESS

FIGURE 6-15

Several chemicals are stored in Area M. These materials are required for normal operation and maintenance activities and include fuel oil, gasoline, and solvents.

Fuel oil is stocked for firing the power plant boilers when there is a curtailment of natural gas. There are two above ground, diked, 20,000-gallon tanks outside Building M-1204.

Some gasoline is stocked in the area for use in forklift trucks. Area M gasoline is stored in a 1,000-gallon above-ground portable steel tank.

Toluene is received in 55-gallon drums. Drums are kept in three location within the area: one in Building M-1206; one in M-1223; and 35 drums on pallets near M-1213.

Polychlorinated Biphenyls (PCBs) are used as non-flammable dielectric fluids in indoor transformers as follows:

M-1205 Equipment Room	430-gallons
M-1217 Equipment Room	480-gallons
M-1219 Equipment Room	195-gallons
M-1224 Equipment Room	430-gallons
M-1227 Equipment Room	480-gallons

Process wastewater is generated from a variety of production activities throughout the area. In review, the waste streams from propellant operations are discharged to the two small pits between Buildings M-1217 and M-1227. These pits do not normally discharge but overflow runs to a ditch draining to the south of the area.

Activities conducted in the northern portion of the area discharge to the pond north of the access road. These include rinse water from the conversion coating operation, neutralized plating waste from the treatment tank outside Building M-1206, and paint spray booth water spray from the building.

Located at the south end of the area, Building M-1219, is a small evaporation pit used to settle propellants from washout activities. The pit does not normally discharge but an overflow line runs into a ditch along the road and southerly to a surface storm drain.

Boiler blowdown from the power plant in Building M-1204 discharges to the ditch west of the building. Wastewater from the regeneration of the dealkinizer in Building M-1203 also discharges to this ditch.

An Imhoff tank receives the majority of sanitary sewage from Area M. The tank and stabilization ponds are located directly south of the area at the access road. Septic tank systems treat sanitary wastewater generated in Buildings M-1228 and M-1231.

The sewage treatment facility contains of an Imhoff tank, sludge drying beds, and two oxidation ponds. The Imhoff tank consists of a two-story tank in which sedimentation is accomplished in the upper compartment and digestion in the lower portion. Sludge is pumped from the tank to the drying beds. Only small quantities of dried sludge are generated from the drying beds. Ocassionally, the dried sludge is removed from the beds and spread as fertilizer on adjacent pasture lands. Overflow from the tank is discharged to the ponds for secondary treatment. The interconnected ponds are each approximately 20 feet wide and 750 feet long. A Parshall flume is located at the effluent of the pond to monitor flows. The effluent from the flume discharges into a normally dry drainage ditch which leads to a small tributary of Station Creek. Station Creek flows into the Leon River, which in turn flows into Little River and on to the Brazos River.

6.11 AREA N - TEXAS A&M AGRICULTURAL EXPERIMENT STATION

The tract of land, approximately 6,000 acres, known as Area N, is now owned by Texas A&M University and managed as a cattle breeding research center. This land was disposed of after the war and was never reactivated by the Air Force or Navy.

During the war this area was the Finished Ammunition Storage group and contained 102 of the small igloo-type buildings described in Area H. The area was designed for a storage capacity of 60 days full time output. This was done in case shipping and storage facilities were not available at ports of embarkation.

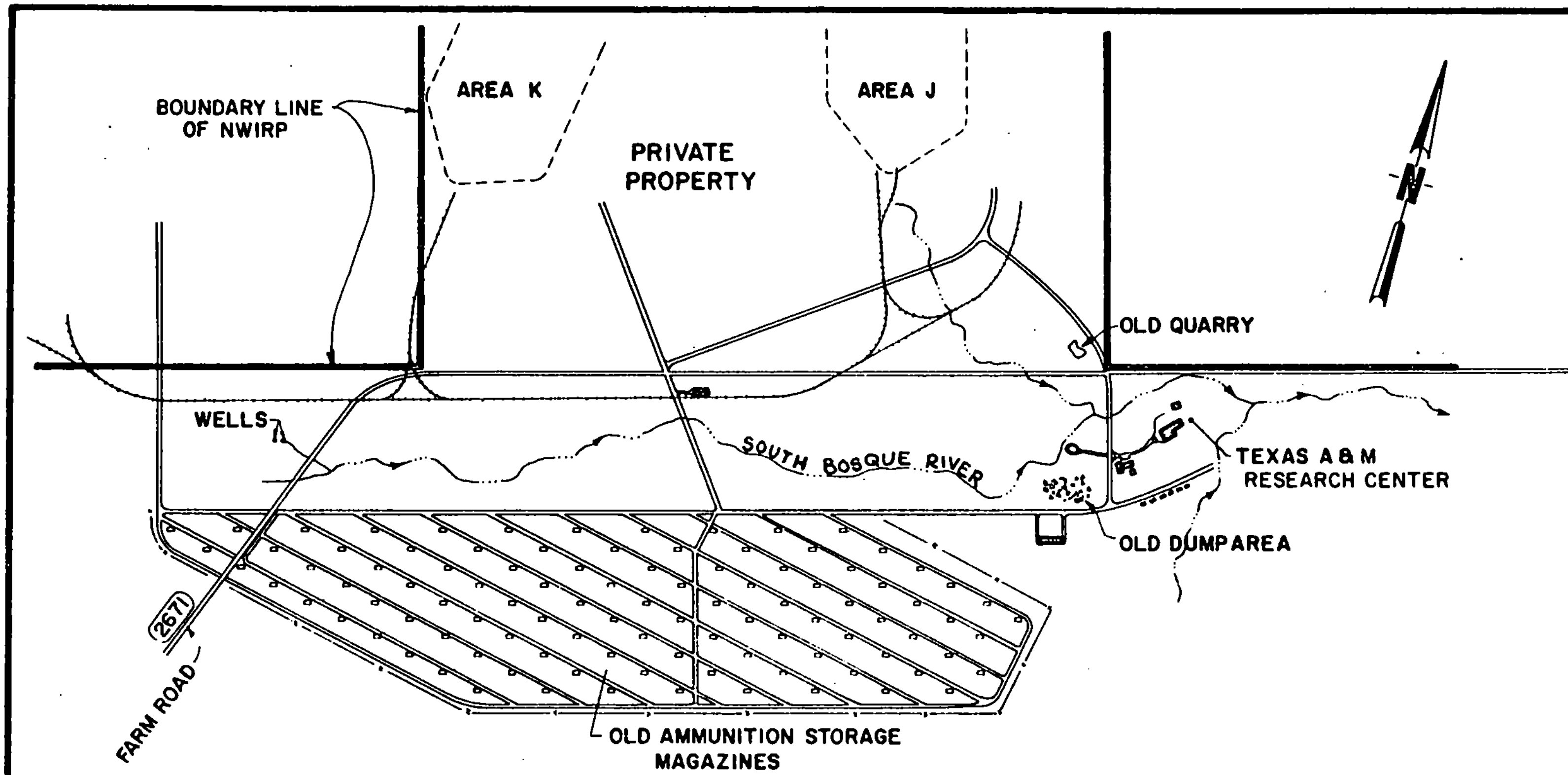
The layout of the area is presented in Figure 6-16. The diagram also shows the approximate location of an old dump believed to contain rubble generated during decontamination and cleanup operations performed at the end of WWII.

This area was not provided with water or sewer service but contains many shallow wells. Some of the wells, like those shown in the upper reaches of the South Bosque, were hand dug by land owners prior to the development of the reserve in 1942.

6.12 AREA P - CLASSIFICATION YARD

This area, located just south of Area C, functioned as the railroad control point or classification yard for incoming and outgoing materials transported by rail. Some 26.5 miles of railroad line connected the various areas of the plant with the Yard and, hence, to the two main outlets, the Santa Fe and Cotton Belt Railway Lines. The yard has not been in operation since the use of railway transport was discontinued some years ago. Building P-401, the Railroad Yard Office, was the only structure constructed within the area.

Sanitary wastewater from the area originally discharged to the sewage disposal plant. The sewer line for the area was plugged in 1968 because of discontinued use.



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AREA N
TEXAS A and M UNIVERSITY RESEARCH CENTER

FIGURE 6-16

6.13 AREA Q - CITY OF McGREGOR WASTEWATER TREATMENT PLANT

A sewage disposal facility was constructed in 1942 as part of Bluebonnet Ordnance Plant to serve the needs of the reserve. A plot plan of the facility is illustrated in Figure 6-17. Initially, all areas, with the exception of H, N and T, were served by the plant sewer system.

Due to increased production demands in late 1944, a fourth load line was constructed. Since there were hydraulic problems associated with the plot (Area M), this portion of the facility was not connected to the existing sewer system. Instead, an Imhoff tank and stabilization ponds were constructed for use in Area M.

In 1966, a consulting engineering firm conducted a sewer system evaluation. As a result of their recommendations, many sewer lines were abandoned and several septic tank systems were created. After the study was completed, the plant's sewer system served only Areas A,B,C, D,F and R. Presently, sanitary and process wastewater from cooling towers, the chemistry laboratory, the photographic facilities, and paint spray booth activities discharge to the city of McGregor treatment plant.

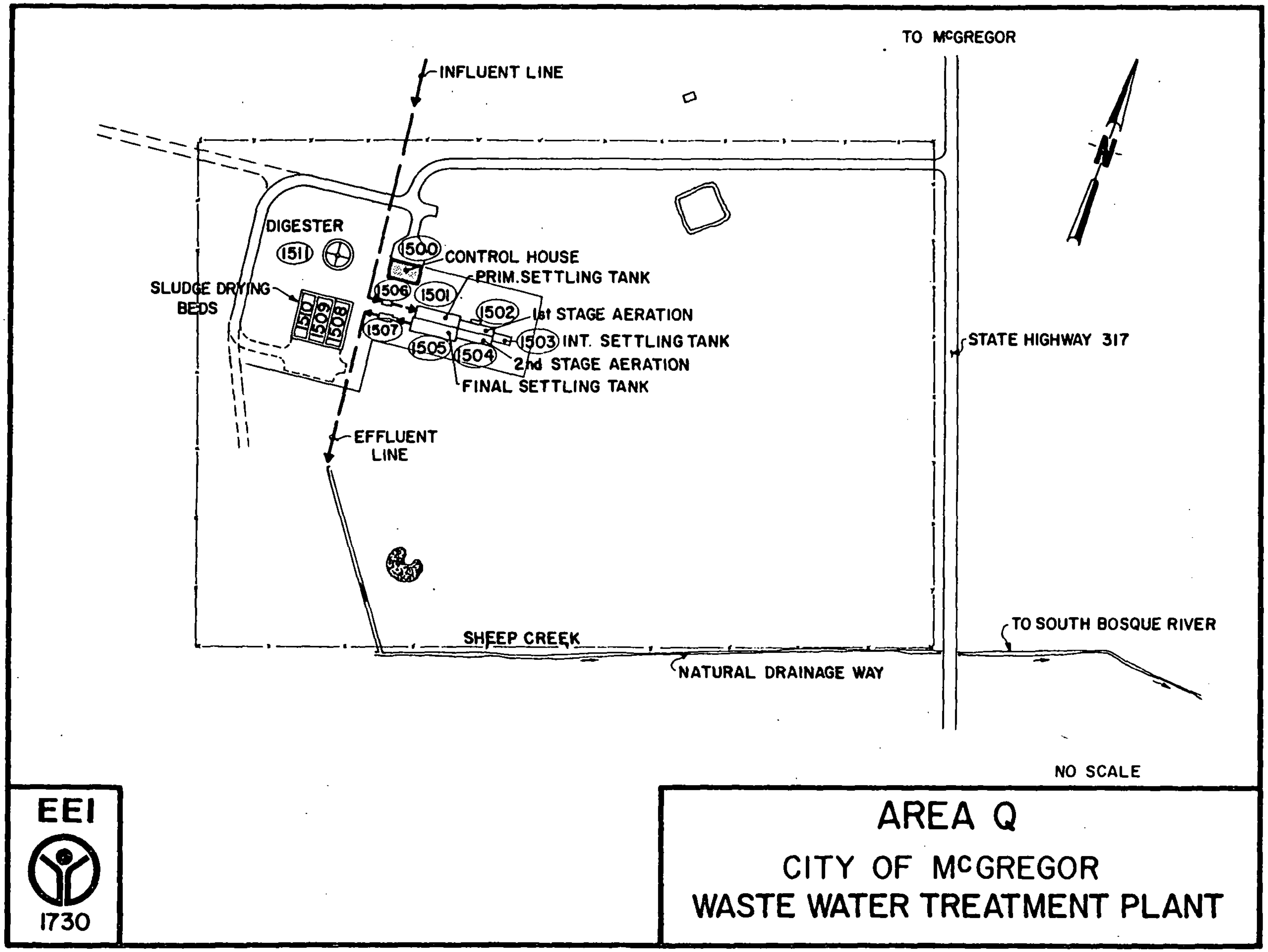
During 1972, the sewage treatment plant and approximately 33.41 acres adjoining the facility (Area Q) were deeded to the City of McGregor. This action was initiated by a letter from the Commanding Officer, Southern Division, Naval Facilities Engineering Command, (12 June 1972) to the General Services Administration (GSA). This letter reported 33.41 acres of land in excess of Navy needs, subject to approval of the Armed Services Committee of Congress. The determination of surplus was made by GSA on 25 August 1972. As a result of this action, this parcel was conveyed by HEW to the City of McGregor for use in the city sewage system with the condition that the city would continue to service NWIRP at a non-discriminatory rate.

An estimated 300,000 gallons of treated effluent are discharged to Sheep Creek daily. NWIRP contributes about 20 percent (or 60,000 gpd) of the discharged flow.

6.14 AREA R - ENVIRONMENTAL AND STATIC TEST

The buildings of this area were constructed by the Air Force in the early 1950's for use by Phillips Petroleum. The area was designed primarily for testing rocket motors. These tests include static firing and conducting various environmental tests. The environmental testing was performed to simulate extreme weather conditions encountered in actual use. The plot plan for this area is shown in Figure 6-18 while Table 6-8 summarizes the major activities conducted in each building.

Occasionally, in the past ten years or so acid etching of steel cases has been performed in the area. This activity is conducted about every two years and generates acid bearing wastes. Prior to the promulgation of the Resource Conservation and Recovery Act, the 15-20 gallons of material is dumped out on the ground within the area.


TO McGREGOR
INFLUENT LINE
DIGESTER
1511
1500
CONTROL HOUSE
PRIM. SETTLING TANK
SLUDGE DRYING BEDS
1510
1509
1508
1506
1501
1502
1st STAGE AERATION
1507
1503
INT. SETTLING TANK
1505
1504
2nd STAGE AERATION
FINAL SETTLING TANK
STATE HIGHWAY 317
N
EFFLUENT LINE
SHEEP CREEK
NATURAL DRAINAGE WAY
TO SOUTH BOSQUE RIVER
NO SCALE
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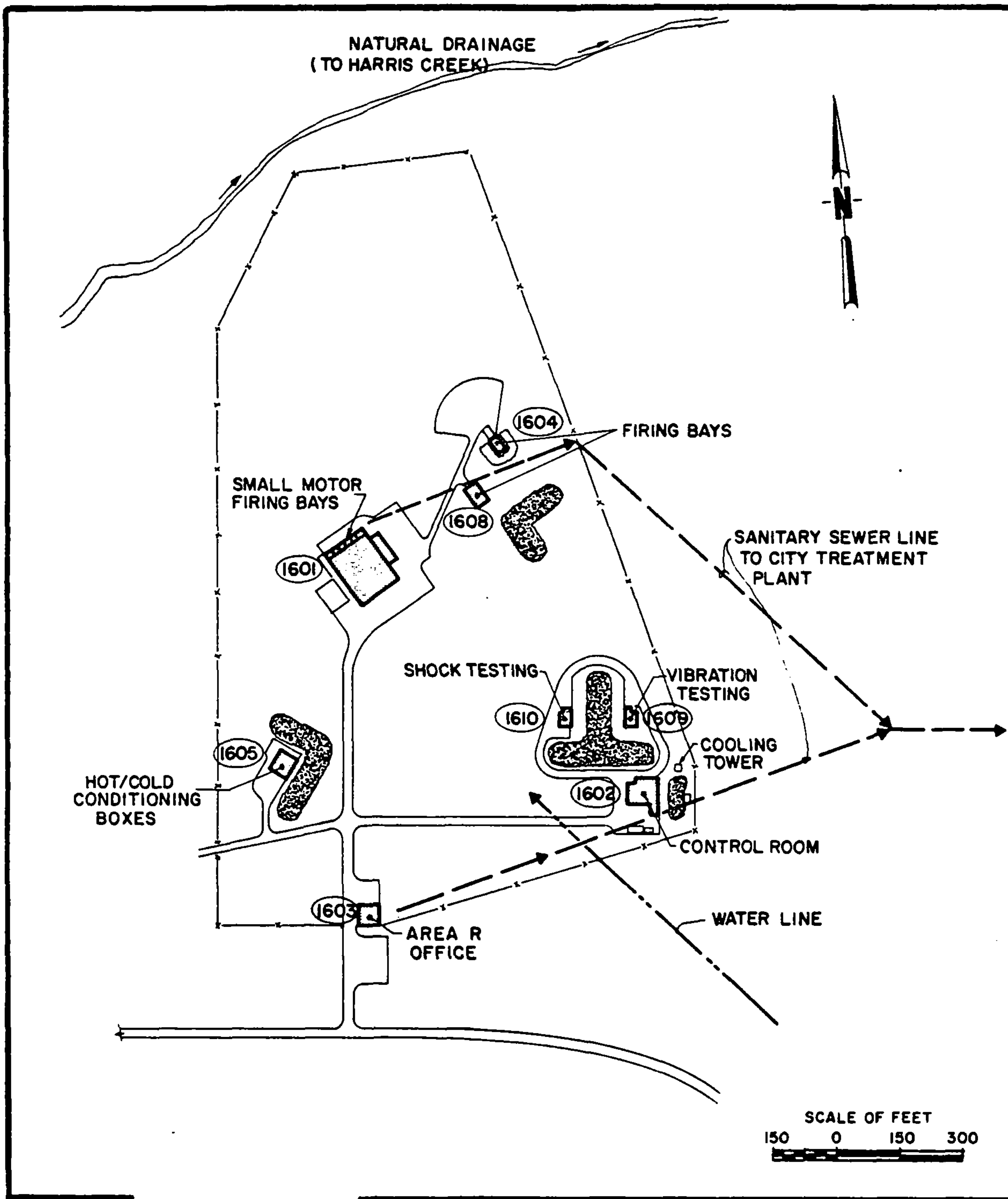
AREA Q
CITY OF McGREGOR
WASTE WATER TREATMENT PLANT

FIGURE 6-17



AREA R

ENVIRONMENTAL AND STATIC TEST

FIGURE 6-18

TABLE 6-8

SUMMARY OF AREA R BUILDINGS

Building Number	Building Description	Building Activity
R-1601	Firing Bays and Equipment Room	Firing bays in northwest end of building for small motors
R-1602	Control Room	Support building for LR-1609 and 1610
R-1603	Aera R Office	Not used for 10 years
R-1604,1608	Firing Bays	Discontinued use in mid-1960s
R-1605	Hot/Cold Conditioning	Hot and cold boxes to simulate extreme temperatures
R-1609	MV Shaker	Vibration testing to simulate wing conditions
R-1610	HY-GEE Shock Machine	Test rocket motors for shock load

As can be seen on the plot plan, the minimal sanitary wastewater generated from the area is discharged to the city treatment plant.

6.15 AREA S - EXPLOSIVES CLASSIFICATION AND DISPOSAL

The area has been designated as the official burning ground for off spec material since the facility was established in 1942. A diagram of the fenced area is shown in Figure 6-19. The burning ground is located in the southeast corner of the plant. It is a 4,800 foot diameter circle (415 acres) with a 4-strand barbed wire fence around the perimeter. The burn pads are positioned in the center and are enclosed by an earthen berm sized to contain the maximum rainfall without surface run-off. The soil is an impervious clay and the site has been approved by the Texas Water Quality Board (TWQB) for an open burning application. The berms prevent spreading of the burn residue through surface run-off, and the clay prevents contamination of groundwater.

Toluene bottoms are burned in a large steel tank located just south of the off spec burning area. This material is not burned directly on the ground; therefore, the probability of contamination is very slight.

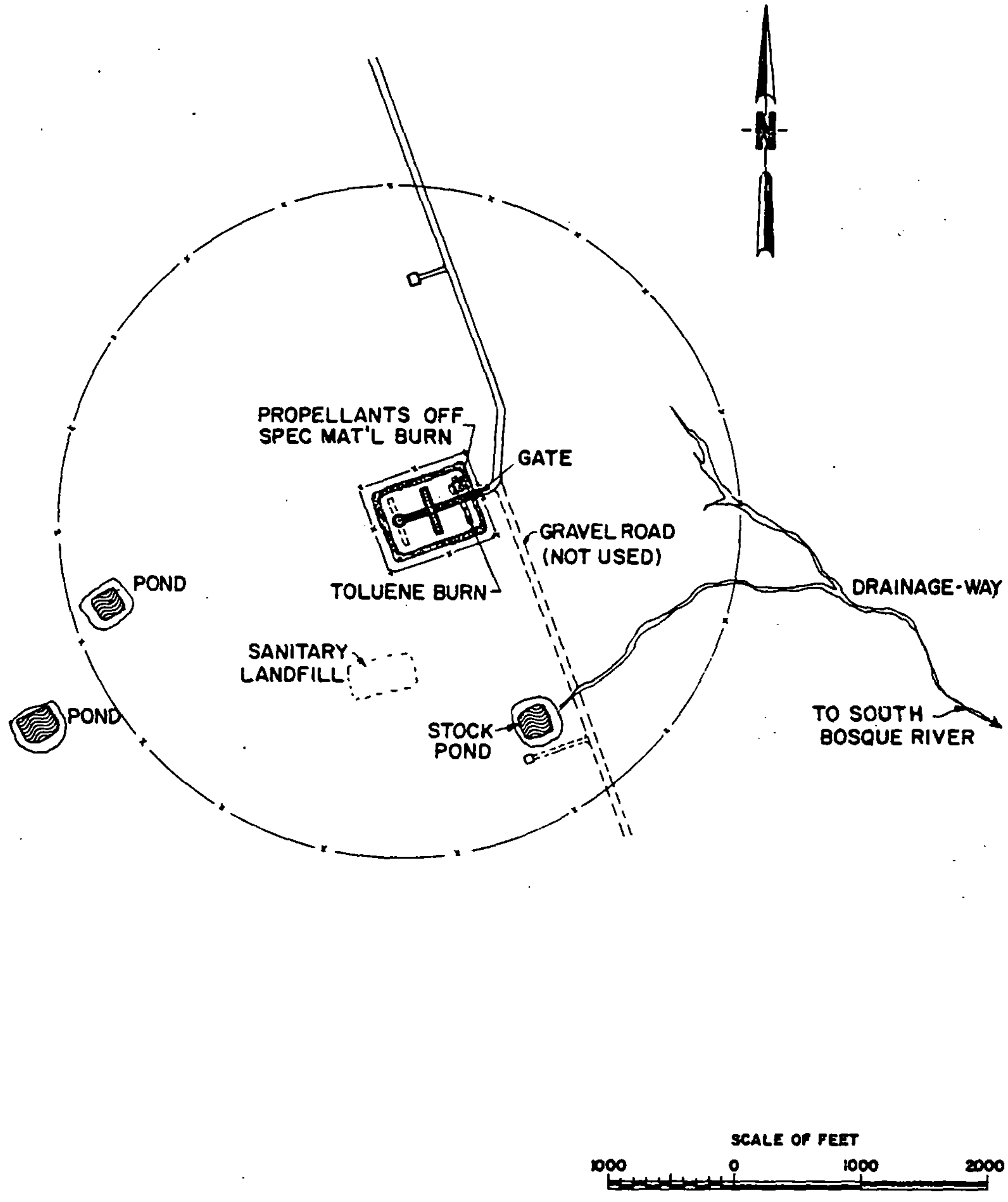
The Texas Air Control Board (TACB) granted written permission to burn the waste propellants and explosive contaminated materials in the early 1970's. These wastes include:

1. Ammonium perchlorate based explosives, about 80% AP
2. Ammonium Nitrate based explosives
3. Solvents contaminated with explosives during manufacturing and clean-up operations.
4. Contaminated rags and paper used during clean-up operations.
5. Toluene bottoms contaminated with explosives during TATB manufacturing operations.

The safety procedures which have been implemented include 2-way radio contact between the burn truck and the fire truck, presence of two employees during the burning operation, and a burning frequency of not less than 16 hours. Since light contamination of air borne combustion products are rapidly dispersed, the only climatic restriction placed on the operation is the banning of burning if winds are in excess of approximately 15-mph, primarily to avoid grass fires.

The nearest public road is over 3/4 mile from the burn pads and the closest residential area is more than a mile away. This separation appears to be more than adequate for the air borne products of combustion. Products of combustion for a typical propellant, explosives and pyrotechics (PEP) operation are illustrated as follows:

HCl	25%
CO	18%



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AREA S

EXPLOSIVES CLASSIFICATION AND DISPOSAL

FIGURE 6-19

CO_2	20%
H_2	2%
N_2	10%
H_2O	20%
Al_2O_3	4%
Fe_2O_3	1%

The site has several ponds within the confined area and, allegedly, contained an old landfill, but the landfill was not in evidence during the visit. Approximate quantities of burned material are presented in Table 6-9.

6.16 AREA T - CRATING AND SHIPPING

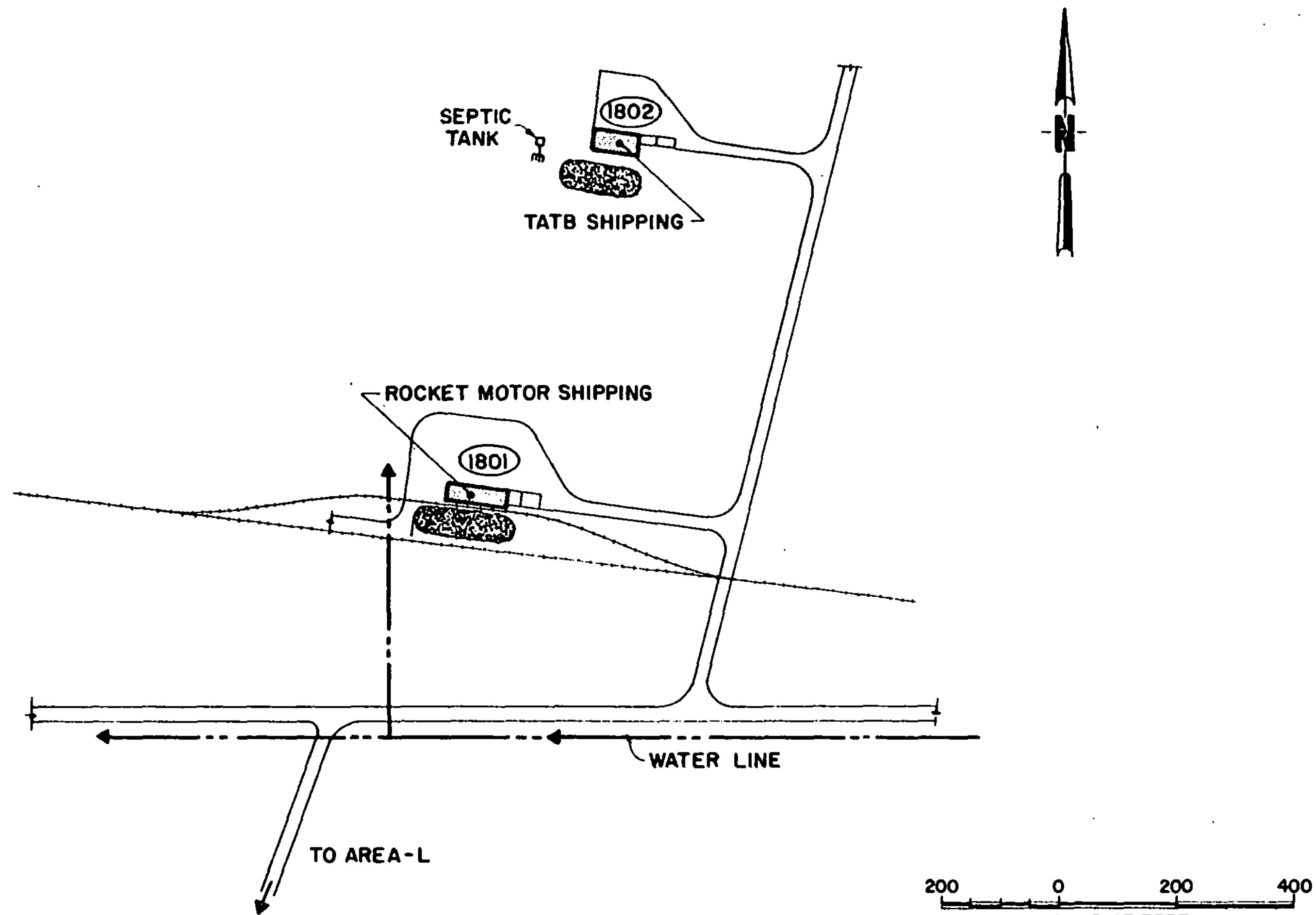
The activities carried out in the area have always included crating and shipping of finished products. During the war only Building T-1801 was in existence and was called Loading Dock #1. The structure designated as T-1802 was constructed in the late 1950's and is presently used for short-term storage and transport of TATB product. A diagram showing the layout of this area is presented in Figure 6-20.

Domestic wastewater generated in this area is discharged to a septic tank. The tank and drain field are located on the west side of T-1802.

TABLE 6-9

OPEN BURNED WASTE PEP
AND PEP CONTAMINATED WASTE

Year	Open Burned PEP (pounds)	Pep Burned in Testing (pounds)
1972	55,000	33,000
1973	130,000	25,000
1974	55,000	15,000
1975	50,000	10,000
1976 (est.)	65,000	10,000
1980 (est.)	160,000	-



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AREA T
CRATING AND SHIPPING

FIGURE 6-20

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Texas Air Control Board, Austin, TX, May 23, 1979 letter from Mr. A. C. Wheatley, Director-Control Strategy Division, to Commander, Southern Division, Naval Facilities Engineering Command, Charleston, SC. Obtained from files of Naval Facilities Engineering Command, Southern Division, Charleston, SC (L. Luecker files regarding hazardous waste management regulations).

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APPENDIX A
SOILS BACKGROUND DATA

DENTON SERIES

The Denton series consists of moderately deep, well drained, slowly permeable soils formed in clayey materials over weakly cemented to fractured indurated limestones and interbedded marls. These upland soils have slopes ranging from 0 to 8 percent.

__Taxonomic Class__: Fine, montmorillonitic, thermic Vertic Calciustolls.

__Typical Pedon__: Denton silty clay--cropland.
(Colors are for dry soil unless otherwise stated.)

Ap--0 to 6 inches; dark grayish brown (10YR 4/2) silty clay, very dark grayish brown (10YR 3/2) moist; moderate medium and fine granular and subangular blocky structure; hard, firm, sticky and plastic; many fine roots; few fine fragments of limestone; calcareous; moderately alkaline; clear smooth boundary. (4 to 8 inches thick)

A11--6 to 14 inches; brown (7.5YR 4/2) silty clay, dark brown (7.5YR 3/2) moist; moderate medium and fine subangular blocky structure; very hard, firm, sticky and plastic; many fine roots; common very fine pores; few partially sealed cracks filled with material from above; few fine fragments of limestone; calcareous; moderately alkaline; gradual wavy boundary. (5 to 15 inches thick)

A12--14 to 26 inches; brown (7.5YR 4/3) silty clay, dark brown (7.5YR 3/3) moist; moderate medium and fine angular and subangular blocky structure; very hard, firm, sticky and plastic; many fine roots; common very fine pores; common shiny pressure faces; vertical cracks filled with dark grayish brown (10YR 4/2) silty clay; few fine fragments of limestone; calcareous; moderately alkaline; gradual wavy boundary. (7 to 16 inches thick)

Bca--26 to 34 inches; brown (7.5YR 5/4) silty clay, brown (7.5YR 4/4) moist; moderate medium and fine angular and subangular blocky structure; hard, firm, sticky and plastic; few fine roots; few dark streaks; common limestone fragments; few fine weakly cemented $CaCO_3$ concretions; calcareous; moderately alkaline; abrupt irregular boundary. (0 to 19 inches thick)

Cca--34 to 38 inches; mixture of about 80 percent flaggy limestone fragments, some of which can be cut with a spade and 20 percent brown (7.5YR 5/4) silty clay; massive, soil is hard, firm, sticky and plastic; few fine roots; limestone flags are up to 2 inches thick and 12 inches across the long axis; common soft masses of $CaCO_3$; calcareous; moderately alkaline; abrupt irregular boundary. (0 to 20 inches thick)

R--38 to 60 inches; fractured limestone that cannot be cut with a spade, interbedded with calcareous clayey marl.

__Type Location__: Coryell County, Texas; from the intersection of U.S. Highway 84 and Texas Highway 36 in Gatesville, Texas; about 2 miles north on Texas Highway 36; then 11 miles east-northeast on Farm Road 929 to Coryell City, Texas; then 4 miles east and south on Farm Roads 929 and 185; then 2 miles west on county road to a T intersection; then north on county road 0.5 mile and 150 feet east of road in field.

__Range in Characteristics__: Solum thickness ranges from 22 to 40 inches over fractured limestone bedrock or limestone bedrock interbedded with marly clay. Fragments of limestone smaller than 3 inches in diameter comprise from 0 to 20 percent of the soil mass. The mollic epipedon ranges from 16 to 35 inches thick. The A horizons have textures of silty clay or clay. Silicate clay content ranges from 35 to 55 percent.

The A horizon is very dark brown (10YR 2/2), dark brown (7.5YR 3/2; 10YR 3/3), brown (7.5YR 4/3, 4/2; 10YR 4/3), dark grayish brown (10YR 4/2; 2.5Y 4/2), or very dark grayish brown (10YR 3/2; 2.5Y 3/2). Chromas of 2 are not due to wetness, but are from the lime. Structure of the A horizon ranges from moderate medium subangular blocky to moderate medium and fine angular blocky.

Some pedons lack B horizons, but where present, the color is brown (7.5YR 5/2, 5/4; 10YR 5/3), yellowish brown (10YR 5/4), dark yellowish brown (10YR 4/4), dark brown (7.5YR 4/4), pale brown (10YR 6/3), light yellowish brown (10YR 6/4), light brownish gray (10YR 6/2), grayish brown (2.5Y 5/2), pale olive (5Y 6/3), or light olive brown (2.5Y 5/4). The B horizon is clay, silty clay, or silty clay loam. Stone lines are in the B horizon of some pedons. Carbonates in the lower part of the A horizon in some pedons and in the B horizon range from 15 to 40 percent of the fine-earth including coarse fragments smaller than 3 inches and contain 5 percent more secondary carbonates than the upper part of the A horizon.

The R layer ranges from fractured limestone bedrock interbedded with calcareous clayey marl to beds of limestone rubble with clayey marl filling the interstices.

__Competing Series__: These are the Austin, Bolar, Krum, Lewisville, Nuvalde, Purves, and Valera series. Austin and Bolar soils contain more than 40 percent carbonates immediately below the A horizon. Krum soils have thicker sola and are not underlain by limestone within 40 inches of the surface. Lewisville soils have A horizons thiner than 20 inches and lack cracks 0.3 inch wide when dry. Nuvalde soils are not underlain with limestone. Purves soils have limestone bedrock within 20 inches of the surface. Valera soils have a petrocalcic horizon.

__Geographic Setting__: Denton soils occur on nearly level to sloping uplands. Slopes are mainly 1 to 3 percent, but range from 0 to 8 percent. The soil formed in a mantle of clayey materials over weakly cemented to fractured indurated limestone and interbedded marls. The average annual precipitation ranges from 28 to 35 inches, average annual temperature ranges from 63° to 68° F., and the annual Thornthwaite P-E indices range from 42 to 58.

__Geographically Associated Soils__: These include the competing Bolar, Krum, Lewisville, and Purves series, as well as the Crawford, San Saba, and Tarrant series. Crawford and San Saba soils have intersecting slickensides. Tarrant soils have limestone bedrock within 20 inches of the surface and contain more than 35 percent coarse fragments.

__Drainage and Permeability__: Well drained. Medium to rapid surface runoff. Slow permeability.

__Use and Vegetation__: Used for cropland, pasture, and range. Cultivated crops are cotton, small grains, and grain sorghums. Native vegetation includes little bluestem, sideoats grama, indiangrass, silver bluestem, Texas wintergrass, and buffalograss. Trees include a few scattered elm and live oak.

__Distribution and Extent__: Mainly in central Texas; but extending into southern Oklahoma. The series is of moderate extent.

Denton Series

<u>Series Established</u>: Denton County, Texas; 1918.

<u>Remarks</u>: The series has been classified in the Rendzina or Grumusol great soil group and as Grumusol-Brunizem intergrade.

National Cooperative Soil Survey
U. S. A.

MLRA(S): 85, 80 DENTON SERIES
REV. GLL.CLG. 10-78
VERTIC CALCIUSTOLLS, FINE, MONTMORILLONITIC, THERMIC

THE DENTON SERIES CONSISTS OF MODERATELY DEEP, CALCAREOUS, SLOWLY PERMEABLE SOILS OF UPLANDS. THE SOIL FORMED IN CALCAREOUS CLAYEY SEDIMENTS OVER FRACTURED LIMESTONES AND MARLS. IN A REPRESENTATIVE PROFILE, THE SURFACE LAYER IS DARK GRAYISH BROWN SILTY CLAY ABOUT 6 INCHES THICK. BELOW THE SURFACE LAYER AND TO A DEPTH OF 34 INCHES IS BROWN SILTY CLAY. THE NEXT LAYER, ABOUT 4 INCHES THICK, IS A MIXTURE OF LIMESTONE FRAGMENTS AND BROWN SILTY CLAY. BELOW 38 INCHES DEPTH IS FRACTURED LIMESTONE INTERBEDDED WITH CLAYEY MARL. SLOPES RANGE FROM 0 TO 8 PERCENT.

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-26	SIC, C	CH, CL	A-7-6	0-10	80-100	80-100	80-100	75-95	49-70	26-46
26-34	SIC, C, SICL	CH, CL	A-7-6	0-20	80-100	80-100	80-100	70-95	41-60	21-40
34-38	WB									

DEPTH (IN.)	CLAY (PCT <2MM)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-26	35-60		0.06-0.2	0.15-0.20	7.9-8.4	-	HIGH	.32	2	4	1-4	HIGH	LOW
26-34	35-60		0.06-0.2	0.15-0.20	7.9-8.4	-	HIGH	.32					
34-38													

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		22-40	SOFT	-		D	-

SANITARY FACILITIES (B)		CONSTRUCTION MATERIAL (B)	
SEPTIC TANK ABSORPTION FIELDS	SEVERE-DEPTH TO ROCK,PERCS SLOWLY	ROADFILL	POOR-AREA RECLAIM,LOW STRENGTH,SHRINK-SWELL
SEWAGE LAGOON AREAS	0-7%: SEVERE-DEPTH TO ROCK 7+%: SEVERE-DEPTH TO ROCK,SLOPE	SAND	IMPROBABLE-EXCESS FINES
SANITARY LANDFILL (TRENCH)	SEVERE-DEPTH TO ROCK,TOO CLAYEY	GRAVEL	IMPROBABLE-EXCESS FINES
SANITARY LANDFILL (AREA)	SEVERE-DEPTH TO ROCK	TOPSOIL	POOR-TOO CLAYEY,SMALL STONES
DAILY COVER FOR LANDFILL	POOR-AREA RECLAIM,TOO CLAYEY,HARD TO PACK		

BUILDING SITE DEVELOPMENT (B)		WATER MANAGEMENT (B)	
		POND RESERVOIR AREA	0-3%: MODERATE-DEPTH TO ROCK 3-8%: MODERATE-DEPTH TO ROCK,SLOPE
SHALLOW EXCAVATIONS	MODERATE-DEPTH TO ROCK,TOO CLAYEY	EMBANKMENTS DIKES AND LEVEES	SEVERE-HARD TO PACK
DWELLINGS WITHOUT BASEMENTS	SEVERE-SHRINK-SWELL	EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DWELLINGS WITH BASEMENTS	SEVERE-SHRINK-SWELL	DRAINAGE	DEEP TO WATER
SMALL COMMERCIAL BUILDINGS	SEVERE-SHRINK-SWELL	IRRIGATION	SLOW INTAKE,PERCS SLOWLY,DEPTH TO ROCK
LOCAL ROADS AND STREETS	SEVERE-LOW STRENGTH,SHRINK-SWELL	TERRACES AND DIVERSIONS	DEPTH TO ROCK,PERCS SLOWLY
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	SEVERE-TOO CLAYEY	GRASSED WATERWAYS	DEPTH TO ROCK,PERCS SLOWLY

REGIONAL INTERPRETATIONS

RECREATIONAL DEVELOPMENT (B)

CAMP AREAS	MODERATE-TOO CLAYEY	PLAYGROUNDS	0-2%: MODERATE-SMALL STONES,TOO CLAYEY 2-6%: MODERATE-SLOPE,SMALL STONES,TOO CLAYEY 6+%: SEVERE-SLOPE
PICNIC AREAS	MODERATE-TOO CLAYEY	PATHS AND TRAILS	MODERATE-TOO CLAYEY

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY		COTTON LINT (LBS)		OATS (BU)		WHEAT (BU)		GRAIN SORGHUM (BU)		CORN (BU)		IMPROVED BERMUDAGR. (AUM)			
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
0-1%	2S		350		60		35		65		40		6.0			
1-3%	2E		350		60		35		65		40		6.0			
3-5%	3E		300		50		30		55		30		5.0			
3-5% ERODED	3E		250		45		25		50		-		5.0			
5-8%	4E		-		45		25		-		-		4.5			

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	COMMON TREES	SITE INDX	TREES TO PLANT
							NONE		

(MANAGEMENT PROBLEMS: EROSION HAZARD through PLANT COMPET.; POTENTIAL PRODUCTIVITY: COMMON TREES, SITE INDX)

WINDBREAKS

CLASS-DETERMINING PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (C)

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
0-3%	GOOD	GOOD	FAIR	-	-	FAIR	POOR	V. POOR	GOOD	-	V. POOR	FAIR
3-5%	FAIR	GOOD	FAIR	-	-	FAIR	POOR	V. POOR	FAIR	-	V. POOR	FAIR
3-5% ERODED	FAIR	GOOD	FAIR	-	-	FAIR	POOR	V. POOR	FAIR	-	V. POOR	FAIR

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION) (D)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE: ALL				
LITTLE BLUESTEM	ANSC2	20				
SIDEOATS GRAMA	BOCU	10				
INDIANGRASS	SONU2	15				
SWITCHGRASS	PAVI2	5				
SILVER BLUESTEM	ANSA	5				
BIG BLUESTEM	ANGE	10				
TEXAS NEEDLEGRASS	STLE5	5				
TALL DROPSEED	SPAS	5				
OTHER PERENNIAL GRASSES	PPGG	5				
OTHER PERENNIAL FORBS	PPFF	15				
OTHER TREES	TTTT	5				
POTENTIAL PRODUCTION (LBS./AC. DRY WT): FAVORABLE YEARS		6500				
NORMAL YEARS		5000				
UNFAVORABLE YEARS		3000				

FOOTNOTES

A ESTIMATES BASED ON ENGINEERING TEST DATA OF 10 PEDONS FROM BANDERA, GILLESPIE, TRAVIS, PARKER AND BOSQUE COUNTIES.
B INTERPRETATIONS BASED ON NATIONAL SOIL HANDBOOK,PART II,SEC.403,MAR.1978.
C WILDLIFE RATINGS BASED ON SOILS MEMORANDUM-74,JAN.1972.
D CLAY LOAM RANGE SITE.

Established Series
Rev. BJW
7/77

CRAWFORD SERIES

The Crawford series consists of moderately deep, well drained very slowly permeable soils formed in a clayey layer underlain by limestone. These upland soils have slopes ranging from 0 to 5 percent.

Taxonomic Class: Fine, montmorillonitic, thermic Udic Chromusterts.

Typical Pedon: Crawford clay--cropland.
(Colors are for dry soil unless otherwise stated.)

Ap--0 to 5 inches; brown (7.5YR 4/2) clay, dark brown (7.5YR 3/2) moist; weak very fine angular blocky structure; very hard, firm, few fine pebbles of quartz; few fine concretions; few fragments of limestone; neutral; abrupt smooth boundary. (4 to 8 inches thick)

A11--5 to 12 inches; brown (7.5YR 4/2) clay, dark brown (7.5YR 3/2) moist; moderate medium angular blocky structure parting to very fine blocky structure; extremely hard, very firm, very sticky, plastic; shiny faces of peds; few fine pebbles of quartz and fragments of limestone; neutral; gradual irregular boundary. (5 to 12 inches thick)

A12--12 to 21 inches; brown (7.5YR 4/2) clay, dark brown (7.5YR 3/2) moist; parallelepipeds part to moderate medium angular blocky and weak very fine blocky structure; extremely hard, very firm, very sticky, plastic; few intersecting slickensides border parallelepipeds tilted 20° to 40° from horizontal; shiny pressure faces; few fine pebbles of quartz and fragments of limestone; neutral; gradual wavy boundary. (6 to 12 inches thick)

A13--21 to 28 inches; dark reddish brown (5YR 3/2) clay, same color moist; crushed peds are (5YR 3/3) moist; parallelepipeds part to moderate or strong medium blocky structure; extremely hard, very firm, very sticky, plastic; fine roots penetrate the peds; common distinct grooved slickensides border parallelepipeds about 1-1/2 inches across the long axis; shiny pressure faces; few pebbles of quartz and limestone; neutral; abrupt irregular boundary. (5 to 15 inches thick)

R--28 to 38 inches; fractured limestone; dark reddish brown clay in the fine crevices.

Type Location: Coryell County, Texas; Bluebonnet Experiment Station on the west edge of McGregor; 3.12 miles west-southwest of the station headquarters and 200 feet east of road in cropland.

Range in Characteristics: Solum thickness to indurated bedrock or limestone interbedded with clayey marls or shales is 20 to 40 inches. Pebbles of limestone and stones comprise 0 to 5 percent of the soil volume. When dry, these soils have cracks ranging from 0.4 to 2.0 inches wide that extend from the surface to depths of 20 inches or more. Cracks open and close each year and remain open for 90 to 150 cumulative days during most years. Gilgai microrelief is indistinct, but slickensides and parallelepipeds are common below 15 inches depth. The texture is clay or silty clay, containing between 42 to 60 percent clay. It ranges from slightly acid through moderately alkaline. A few pedons are calcareous.

The Ap and A11 horizons are dark reddish brown (5YR 2/2, 3/2, 3/3), reddish brown (5YR 4/3, 5/3), dark brown (7.5YR 3/2, 4/2; 10YR 3/3, 4/3), brown (10YR 5/3), very dark brown (10YR 2/2), dark or very dark grayish brown (10YR 3/2, 4/2). Moist chromas and values are less than 3.5. Less than half of some pedons have chromas of less than 1.5 in the Ap and A11 horizons.

The A12 and A13 horizons are dark reddish brown (5YR 2/2, 3/2, 3/3), reddish brown (5YR 4/3, 5/3), dark brown (7.5YR 3/2, 4/2), or brown (7.5YR 5/2). A few pedons have moist color values of 4 below a depth of 12 inches. A few pedons have secondary lime at the contact of the limestone bedrock.

Competing Series: These are the Anhalt, Heiden, Luling, San Saba, Stamford, and Tobosa series. Anhalt soils have more than 60 percent clay. Heiden soils have hue of 10YR or yellower throughout and lack limestone within depths of 40 inches. Luling soils have yellower hues and lack limestone within 40 inches. San Saba soils have chroma of less than 1.5 throughout the upper 12 inches. Stamford and Tobosa soils have cracks that remain open for more than 150 days most years and lack limestone bedrock within depths of 40 inches.

Geographic Setting: Crawford soils are on nearly level or gently sloping uplands. Slope gradients are mainly less than 2 percent and range from 0 to 5 percent. The soil formed in a clayey layer underlain by limestone at depths of 20 to 40 inches. The mean annual precipitation ranges from 24 to 34 inches; average annual temperature from 63° to 70° F.; Thornthwaite annual P-E index from 36 to 56.

Geographically Associated Soils: These are the competing San Saba series, and the Bexar, Denton, Hensley, Lindy, Speck, and Yates series. Bexar, Hensley, Lindy, and Speck soils have B2t horizons. In addition, Hensley and Speck soils have sola less than 20 inches thick. Denton soils lack intersecting slickensides. Yates soils have more than 35 percent coarse fragments, and limestone bedrock is within 14 inches of the surface.

Drainage and Permeability: Well drained; slow to medium runoff; very slow permeability when the soil is saturated, rapid when it is dry and cracked.

Use and Vegetation: Used for cropland, pasture, and range. Crops grown are small grains, grain sorghums, and cotton. Native vegetation is little bluestem, sideoats grama, blue grama, and buffalograss. Trees are live oak, Spanish oak, post oak, juniper, and elm.

Distribution and Extent: The Grand Prairie and Edwards Plateau of central Texas. The series is extensive.

Series Established: McLennan County (Waco area), Texas; 1905.

Remarks: The Crawford series was formerly classified in the Grumusol great soil group.

National Cooperative Soil Survey
U. S. A.

T30623

SOIL INTERPRETATIONS RECORD

MLRA(S): 81, 86 — CRAWFORD SERIES

REV. BJA, 8-79

LDIC CHROMUSTERTS, FINE, MONTMORILLONITIC, THERMIC

THE CRAWFORD SERIES CONSISTS OF MODERATELY DEEP, WELL-DRAINED, NEARLY LEVEL TO GENTLY SLOPING SOILS OF UPLANDS. THE SOIL FORMED IN CLAYEY SEDIMENTS OVER LIMESTONE BEDROCK. IN A REPRESENTATIVE PROFILE, THE SURFACE LAYER IS BROWN CLAY, 21 INCHES THICK. THE NEXT LAYER IS DARK REDDISH-BROWN CLAY, 7 INCHES THICK. THE SUBSTRATUM, BELOW 28 INCHES, IS HARD, FRACTURED LIMESTONE. SLOPES RANGE FROM 0 TO 5 PERCENT.

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-28	C, SIC	CH	A-7-6	0-5	95-100	85-100	75-100	70-100	51-80	30-60
28-38	WB									

DEPTH (IN.)	CLAY (PCT <2MM)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND ERod. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-28	40-60		<0.06	0.14-0.18	6.1-8.4	-	VERY HIGH	.32	2	4	1-3	HIGH	LOW
28-38													

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		20-40	HARD	-		D	-

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS	SEVERE-DEPTH TO ROCK, PERCS SLOWLY
SEWAGE LAGOON AREAS	SEVERE-DEPTH TO ROCK
SANITARY LANDFILL (TRENCH)	SEVERE-DEPTH TO ROCK, TOO CLAYEY
SANITARY LANDFILL (AREA)	SEVERE-DEPTH TO ROCK
DAILY COVER FOR LANDFILL	POOR-AREA RECLAIM, TOO CLAYEY, HARD TO PACK

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS	SEVERE-DEPTH TO ROCK, CUTBANKS CAVE
DWELLINGS WITHOUT BASEMENTS	SEVERE-SHRINK-SWELL
DWELLINGS WITH BASEMENTS	SEVERE-DEPTH TO ROCK, SHRINK-SWELL
SMALL COMMERCIAL BUILDINGS	SEVERE-SHRINK-SWELL
LOCAL ROADS AND STREETS	SEVERE-LOW STRENGTH, SHRINK-SWELL
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	SEVERE-TOO CLAYEY

CONSTRUCTION MATERIAL (B)

ROADFILL	POOR-AREA RECLAIM, LOW STRENGTH, SHRINK-SWELL
SAND	IMPROBABLE-EXCESS FINES
GRAVEL	IMPROBABLE-EXCESS FINES
TOPSOIL	POOR-TOO CLAYEY

WATER MANAGEMENT (B)

POND RESERVOIR AREA	MODERATE-DEPTH TO ROCK
EMBANKMENTS DIKES AND LEVEES	SEVERE-HARD TO PACK
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE	DEEP TO WATER
IRRIGATION	SLOW INTAKE, PERCS SLOWLY, DEPTH TO ROCK
TERRACES AND DIVERSIONS	DEPTH TO ROCK, PERCS SLOWLY
GRASSED WATERWAYS	DEPTH TO ROCK, PERCS SLOWLY

REGIONAL INTERPRETATIONS

RECREATIONAL DEVELOPMENT (B)

CAMP AREAS	MODERATE-PERCS SLOWLY,TOO CLAYEY	PLAYGROUNDS	0-2%: MODERATE-SMALL STONES,TOO CLAYEY 2-6%: MODERATE-SLOPE,SMALL STONES,TOO CLAYEY
PICNIC AREAS	MODERATE-TOO CLAYEY,PERCS SLOWLY	PATHS AND TRAILS	MODERATE-TOO CLAYEY

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	COTTON LINT (LBS) NIRR	COTTON LINT (LBS) IRR.	GRAIN SORGHUM (BU) NIRR	GRAIN SORGHUM (BU) IRR.	OATS (BU) NIRR	OATS (BU) IRR.	WHEAT (BU) NIRR	WHEAT (BU) IRR.	IMPROVED BERMUDAGR. (AUM) NIRR	IMPROVED BERMUDAGR. (AUM) IRR.	NIRR	IRR.	NIRR	IRR.
0-1%	3S		400		80		60		30		7.0					
1-3%	3E		350		75		60		30		6.5					
3-6%	3E		300		65		55		25		6.0					

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	COMMON TREES	SITE INDX	TREES TO PLANT
							NONE		

WINDBREAKS

CLASS-DETERMINING PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (C)

CLASS-DETERMINING PHASE	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
0-3%	FAIR	FAIR	FAIR	-	-	FAIR	POOR	V. POOR	FAIR	-	V. POOR	FAIR
3-6%	FAIR	FAIR	FAIR	-	-	FAIR	POOR	V. POOR	FAIR	-	V. POOR	FAIR

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION) (D)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE: ALL				
LITTLE BLUESTEM	ANSC2	40				
BIG BLUESTEM	ANGE	10				
INDIANGRASS	SONU2	5				
SIDEOATS GRAMA	BOCU	5				
TALL DROPSEED	SPAS	5				
SILVER BLUESTEM	ANSA	5				
TEXAS NEEDLEGRASS	STLE5	5				
BUFFALOGRASS	BUDA	5				
OTHER TREES	TTTT	4				
OTHER SHRUBS	SSSS	4				
OTHER PERENNIAL FORBS	PPFF	10				
POTENTIAL PRODUCTION (LBS./AC. DRY WT):						
FAVORABLE YEARS		8000				
NORMAL YEARS		6000				
UNFAVORABLE YEARS		3500				

FOOTNOTES

A ESTIMATES BASED ON ENGINEERING TEST DATA FROM BEXAR AND TRAVIS COUNTIES, TEXAS.

B RATINGS BASED ON NSH, PART II, SECTION 403, 3-78.

C WILDLIFE RATINGS BASED ON SOILS MEMORANDUM-74 JAN. 1972.

D DEEP REDLAND RANGE SITE.

SAN SABA SERIES

The San Saba series consists of moderately deep, moderately well drained, very slowly permeable soils that formed in clayey sediments over limestone. These upland soils have slopes ranging from 0 to 5 percent.

Taxonomic Class: Fine, montmorillonitic, thermic Udic Pellusterts.

Typical Pedon: San Saba clay--cropland.
(Colors are for dry soil unless otherwise stated.)

Ap--0 to 4 inches; dark gray (10YR 4/1) clay, very dark gray (10YR 3/1) moist; moderate fine and medium granular structure; extremely hard, very firm; few fine roots; calcareous, mildly alkaline; clear smooth boundary. (4 to 6 inches thick)

A1--4 to 19 inches; very dark gray (10YR 3/1) clay, black (10YR 2/1) moist; moderate, medium angular blocky structure; extremely hard, very firm; few fine roots; streaks of dark gray in old crack fillings; shiny ped faces; few fine dark concretions; calcareous, mildly alkaline; gradual wavy boundary. (8 to 26 inches thick)

AC--19 to 35 inches; dark gray (10YR 4/1) clay, very dark gray (10YR 3/1) moist; intersecting slickensides border parallelepipeds tilted 30° to 45° from horizontal, these part to moderate fine angular blocky structure; extremely hard, very firm; few $CaCO_3$ concretions; few fine dark concretions; calcareous, moderately alkaline; abrupt smooth boundary. (12 to 20 inches thick)

R--35 to 38 inches; gray indurated limestone; fractured; hardness of about 3 Moh's scale.

Type Location: Bell County, Texas; 1,600 feet west of a junction of a private road and Texas Highway 317; from a point 1.1 miles north of the junction of Texas Highway 317 and Texas Highway 36; this junction is 6 miles west of Temple via Highway 36.

Range in Characteristics: Thickness of the soil to limestone or limestone interbedded with clay or chalk ranges from 24 to 40 inches. When dry, these soils have cracks from 1 to 3 inches wide that extend from the surface to depths of 20 inches or more. Cracks open and close on the average more than once each year, and they remain open from 90 to 150 cumulative days in most years. Virgin areas have gilgai microrelief of knolls 3 to 6 inches higher than depressions, and the distance between the center of the knolls and the center of the depressions ranges from 6 to 12 feet. Intersecting slickensides are between a depth of 10 inches and the limestone. Clay content ranges from 45 to 60 percent. The solum is commonly mildly to moderately alkaline and calcareous, but some pedons are noncalcareous to depths of 20 inches. Some pedons contain 5 to 10 percent by volume of fragments of limestone ranging from 1/2 to 2 inches in diameter. Dark concretions in the soil range from few to common.

The A horizon is dark gray (10YR 4/1; N 4/0) or very dark gray (10YR 3/1; N 3/0). The AC horizon is dark gray (10YR 4/1; N 4/0; 5Y 4/1), gray (10YR 5/1; N 5/0; 5Y 5/1), grayish brown (10YR 5/2; 2.5Y 5/2), dark grayish brown (10YR 4/2; 2.5Y 4/2), olive gray (5Y 4/2, 5/2), or olive (5Y 4/3, 5/3). Most pedons that have chroma of 2 or 3 are distinctly mottled with gray.

Competing Series: These are the Branyon, Burleson, Crawford, Denton, Heiden, Houston Black, Randall, and Tiocano series. Branyon, Burleson, Houston Black, and Randall soils lack limestone within depths of 40 inches. Crawford, Denton, and Heiden soils have chroma of more than 1.5 in the A horizons, and Denton soils lack intersecting slickensides. Tiocano soils have mean annual soil temperature of more than 72° F.

Geographic Setting: San Saba soils are on nearly level or gently sloping uplands. Slope gradients range from 0 to 5 percent, but are dominantly from 0.5 to 2 percent. The soil formed in calcareous clays underlain by limestone or chalk at depths of 24 to 40 inches. The climate is moist to dry subhumid. Average rainfall is 28 to 40 inches. Thornthwaite P-E indices are 40 to 64. The mean annual temperature is 64° to 70° F.

Geographically Associated Soils: These are the competing Crawford and Denton series, and the Bolar, Krum, Purves, and Tarrant series. Bolar soils have more than 40 percent carbonates and lack intersecting slickensides. Krum soils have chroma of more than 1.5 and lack intersecting slickensides. Purves soils have sola of less than 20 inches. Tarrant soils have clayey-skeletal sola of less than 20 inches.

Drainage and Permeability: Moderately well drained; slow to medium runoff; very slow permeability when the soil is saturated, and rapid when it is dry and cracked.

Use and Vegetation: In cultivation, pasture and range. Cultivated crops are mostly grain sorghums, small grain, and cotton. Native range is mid and tall grasses and a widely spaced overstory of live oak. Most pasture areas are planted to coastal bermudagrass.

Distribution and Extent: Central Texas and southern Oklahoma. In the Edwards Plateau, the Grand Prairie and small areas in the Texas Blackland Prairies. The series is of moderate extent.

Series Established: San Saba County, Texas; 1916.

Remarks: The San Saba series was formerly classified as Grumusols.

National Cooperative Soil Survey
U. S. A.

RECREATIONAL DEVELOPMENT (C)

CAMP AREAS	MODERATE-TOO CLAYEY, PERCS SLOWLY	PLAYGROUNDS	SEVERE-TOO CLAYEY
PICNIC AREAS	MODERATE-TOO CLAYEY	PATHS AND TRAILS	MODERATE-TOO CLAYEY

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	COTTON LINT (LBS) NIRR	COTTON LINT (LBS) IRR.	GRAIN SORGHUM (BU) NIRR	GRAIN SORGHUM (BU) IRR.	WHEAT (BU) NIRR	WHEAT (BU) IRR.	OATS (BU) NIRR	OATS (BU) IRR.	CORN (BU) NIRR	CORN (BU) IRR.	IMPROVED BERMUDAGR. (AUM) NIRR	IMPROVED BERMUDAGR. (AUM) IRR.	NIRR	IRR.
0-1%	3S		400		90		30		60		50		6.0			
1-3%	3E		350		75		30		55		45		6.0			
3-5%	3E		300		55		25		50		40		5.5			

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	COMMON TREES	SITE INDX	TREES TO PLANT
							NONE		

(MANAGEMENT PROBLEMS: EROSION HAZARD through PLANT COMPET.; POTENTIAL PRODUCTIVITY: COMMON TREES, SITE INDX)

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (D)

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS: GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	POTENTIAL AS HABITAT FOR: OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
0-3%	FAIR	FAIR	FAIR	-	-	FAIR	POOR	POOR	FAIR	-	POOR	FAIR
3-8%	FAIR	FAIR	FAIR	-	-	FAIR	POOR	V. POOR	FAIR	-	V. POOR	FAIR

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION) (E)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE: ALL				
LITTLE BLUESTEM	ANSC2	45				
BIG BLUESTEM	ANGE	10				
INDIANGRASS	SONU2	10				
SWITCHGRASS	PAVI2	5				
TEXAS NEEDLEGRASS	STLE5	5				
SIDEOATS GRAMA	BOCU	5				
SILVER BLUESTEM	ANSA	5				
OTHER PERENNIAL FORBS	PPFF	10				
OTHER SHRUBS	SSSS	3				
OTHER TREES	TTTT	2				
[illegible]						
[illegible]		[illegible]				
[illegible]		[illegible]				
[illegible]		[illegible]				

FOOTNOTES

A ESTIMATES BASED ON ENGINEERING TEST DATA OF 2 PEDONS FROM [illegible] AND [illegible] COUNTIES TEXAS.
B RATINGS BASED ON "GUIDE FOR INTERPRETING ENGINEERING USES OF SOILS", NOV. 1971.
C RECREATION RATINGS BASED ON [illegible]
D WILDLIFE RATINGS BASED ON [illegible]
E [illegible]
F RATINGS BASED ON [illegible]

MLRA(S): 81, 85
REV. WJW, 5-79
UDIC PELLUSTERTS, FINE, MONTMORILLONITIC, THERMIC

SAN SABA SERIES

THE SAN SABA SERIES CONSISTS OF MODERATELY DEEP, MODERATELY WELL DRAINED, NEARLY LEVEL TO GENTLY SLOPING SOILS ON UPLANDS. THE SOIL FORMED IN CALCAREOUS CLAYS. IN A REPRESENTATIVE PROFILE, THE SURFACE LAYER IS CLAY 19 INCHES THICK AND IS DARK GRAY IN THE UPPER PART AND VERY DARK GRAY IN THE LOWER PART. THE NEXT LAYER IS DARK GRAY CLAY 16 INCHES THICK. THE SUBSTRATUM, BELOW 35 INCHES, IS HARD LIMESTONE. SLOPE RANGE FROM 0 TO 5 PERCENT.

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-35	C	CH	A-7-6	0	90-100	85-100	80-100	75-100	55-70	30-45
35-38	WB									

DEPTH (IN.)	CLAY (PCT <2MM)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-35	45-60		<0.06	0.15-0.20	7.4-8.4	-	VERY HIGH	.32	2	4	1-4	HIGH	LOW
35-38													

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		29-40	HARD	-		D	-

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS	SEVERE-DEPTH TO ROCK,PERCS SLOWLY
SEWAGE LAGOON AREAS	SEVERE-DEPTH TO ROCK
SANITARY LANDFILL (TRENCH)	SEVERE-DEPTH TO ROCK,TOO CLAYEY
SANITARY LANDFILL (AREA)	SEVERE-DEPTH TO ROCK
DAILY COVER FOR LANDFILL	POOR-AREA RECLAIM,TOO CLAYEY,HARD TO PACK

CONSTRUCTION MATERIAL (B)

ROADFILL	POOR-AREA RECLAIM,LOW STRENGTH,SHRINK-SWELL
SAND	IMPROBABLE-EXCESS FINES
GRAVEL	IMPROBABLE-EXCESS FINES
TOPSOIL	POOR-TOO CLAYEY

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS	SEVERE-DEPTH TO ROCK,CUTBANKS CAVE
DWELLINGS WITHOUT BASEMENTS	SEVERE-SHRINK-SWELL
DWELLINGS WITH BASEMENTS	SEVERE-DEPTH TO ROCK,SHRINK-SWELL
SMALL COMMERCIAL BUILDINGS	SEVERE-SHRINK-SWELL
LOCAL ROADS AND STREETS	SEVERE-LOW STRENGTH,SHRINK-SWELL
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	SEVERE-TOO CLAYEY

WATER MANAGEMENT (B)

POND RESERVOIR AREA	0-3%: MODERATE-DEPTH TO ROCK 3-5%: MODERATE-DEPTH TO ROCK,SLOPE
EMBANKMENTS DIKES AND LEVEES	SEVERE-HARD TO PACK
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE	DEEP TO WATER
IRRIGATION	SLOW INTAKE,PERCS SLOWLY,DEPTH TO ROCK
TERRACES AND DIVERSIONS	DEPTH TO ROCK,PERCS SLOWLY
GRASSED WATERWAYS	DEPTH TO ROCK,PERCS SLOWLY

REGIONAL INTERPRETATIONS

RECREATIONAL DEVELOPMENT (B)

CAMP AREAS	MODERATE-PERCS SLOWLY,TOO CLAYEY	PLAYGROUNDS	0-2%: MODERATE-SMALL STONES,TOO CLAYEY 2-5%: MODERATE-SLOPE,SMALL STONES,TOO CLAYEY
PICNIC AREAS	MODERATE-TOO CLAYEY,PERCS SLOWLY	PATHS AND TRAILS	MODERATE-TOO CLAYEY

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	CAPABILITY IRR.	COTTON LINT (LBS) NIRR	COTTON LINT (LBS) IRR.	GRAIN SORGHUM (BU) NIRR	GRAIN SORGHUM (BU) IRR.	WHEAT (BU) NIRR	WHEAT (BU) IRR.	OATS (BU) NIRR	OATS (BU) IRR.	CORN (BU) NIRR	CORN (BU) IRR.	IMPROVED BERMUDAGR. (AUM) NIRR	IMPROVED BERMUDAGR. (AUM) IRR.	NIRR	IRR.
0-1%	3E		400		60		30		60		50		6.0			
1-3%	3E		350		75		30		55		45		6.0			
3-5%	3E		300		65		28		50		40		5.5			

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	COMMON TREES	SITE INDX	TREES TO PLANT
							NONE		

WINDBREAKS

CLASS-DETERMINING PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (C)

CLASS-DETERMINING PHASE	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	UPLAND WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
0-3%	FAIR	FAIR	FAIR	-	-	FAIR	POOR	POOR	FAIR	-	POOR	FAIR
3-5%	FAIR	FAIR	FAIR	-	-	FAIR	POOR	V. POOR	FAIR	-	V. POOR	FAIR

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION) (D)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE: ALL				
LITTLE BLUESTEM	ANSC2	45				
BIG BLUESTEM	ANGE	10				
INDIANGRASS	SONU2	10				
SWITCHGRASS	PAVI2	5				
TEXAS NEEDLEGRASS	STLE5	5				
SIDEOATS GRAMA	BOCU	5				
SILVER BLUESTEM	ANSA	5				
OTHER PERENNIAL FORBS	PPFF	10				
OTHER SHRUBS	SSSS	3				
OTHER TREES	TTTT	2				
POTENTIAL PRODUCTION (LBS./AC. DRY WT): FAVORABLE YEARS		6000				
NORMAL YEARS		5000				
UNFAVORABLE YEARS		3500				

FOOTNOTES

A ESTIMATES BASED ON ENGINEERING TEST DATA OF 3 PEDONS FROM CLARK AND COKE COUNTIES, TEXAS.
B RATINGS BASED ON NSH, PART II, SECTION 403, 1-73.
C WILDLIFE RATINGS BASED ON SOILS MEMORANDUM-74, JAN. 1972.
D BLACKLAND RANGE SITE.

TX0088

SOIL INTERPRETATIONS RECORD

MLRA(S): 87, 84
REV. CLG,GLL, 3-79
ARENIC PALEUSTALFS, LOAMY, SILICEOUS, THERMIC

SILSTID SERIES

THE SILSTID SERIES CONSISTS OF DEEP, WELL DRAINED, NEARLY LEVEL TO UNDULATING SOIL OF UPLANDS. THE SOIL FORMED IN SANDY AND LOAMY MATERIAL AND INTERBEDDED SANDSTONE. IN A REPRESENTATIVE PROFILE, THE SURFACE LAYER IS BROWNISH FINE SAND ABOUT 37 INCHES THICK. THE SUBSOIL IS A YELLOWISH SANDY CLAY LOAM THAT EXTENDS TO DEPTHS OF MORE THAN 60 INCHES. SLOPE GRADIENTS RANGE FROM 0 TO 8 PERCENT

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-37	FS, LFS	SM, SP-SM	A-2-4	0	95-100	95-100	90-100	10-25	<25	NP-3
37-52	SCL, L, FSL	SC, CL, SM-SC, CL-ML	A-4,A-6,A-2-4,A-2-6	0	95-100	95-100	80-100	30-55	20-40	4-22
52-60	SCL, L, FSL	SC, CL, SM-SC, CL-ML	A-4,A-6,A-2-4,A-2-6	0	95-100	85-100	70-100	22-55	20-40	4-22

DEPTH (IN.)	CLAY (PCT <2MM)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND ERODIBILITY GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CORROSIVITY CONCRETE
0-37	3-12		6.0-20	0.05-0.10	5.6-7.3	-	LOW	.17	5	-	<1	MODERATE	MODERATE
37-52	18-32		0.6-2.0	0.12-0.17	5.1-6.5	-	LOW	.24					
52-60	18-32		0.6-2.0	0.10-0.16	5.1-6.5	-	LOW	.24					

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		>60		-		A	-

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS	SLIGHT
SEWAGE LAGOON AREAS	0-7%: SEVERE-SEEPAGE 7-8%: SEVERE-SEEPAGE,SLOPE
SANITARY LANDFILL (TRENCH)	LFS: MODERATE-TOO SANDY FS: SEVERE-TOO SANDY
SANITARY LANDFILL (AREA)	SEVERE-SEEPAGE
DAILY COVER FOR LANDFILL	LFS: POOR-SEEPAGE FS: POOR-SEEPAGE,TOO SANDY

CONSTRUCTION MATERIAL (B)

ROADFILL	GOOD
SAND	IMPROBABLE-THIN LAYER
GRAVEL	IMPROBABLE-TOO SANDY
TOPSOIL	LFS: FAIR-TOO SANDY FS: POOR-TOO SANDY

BUILDING SITE DEVELOPMENT (B)

SHALLOW EXCAVATIONS	SEVERE-CUTBANKS CAVE
DWELLINGS WITHOUT BASEMENTS	SLIGHT
DWELLINGS WITH BASEMENTS	SLIGHT
SMALL COMMERCIAL BUILDINGS	0-4%: SLIGHT 4-8%: MODERATE-SLOPE
LOCAL ROADS AND STREETS	SLIGHT
LAWNS, LANDSCAPING AND GOLF FAIRWAYS	MODERATE-DROUGHTY.

WATER MANAGEMENT (B)

POND RESERVOIR AREA	MODERATE-SEEPAGE
EMBANKMENTS DIKES AND LEVEES	SEVERE-SEEPAGE,PIPING
EXCAVATED PONDS AQUIFER FED	SEVERE-NO WATER
DRAINAGE	DEEP TO WATER
IRRIGATION	0-3%: DROUGHTY,FAST INTAKE 3-8%: DROUGHTY,FAST INTAKE,SLOPE
TERRACES AND DIVERSIONS	TOO SANDY
GRASSED WATERWAYS	DROUGHTY

REGIONAL INTERPRETATIONS

RECREATIONAL DEVELOPMENT (B)

CAMP AREAS	LFS: MODERATE-TOO SANDY FS: SEVERE-TOO SANDY	PLAYGROUNDS	0-2% LFS: MODERATE-TOO SANDY 2-6% LFS: MODERATE-SLOPE,TOO SANDY 6+% LFS: SEVERE-SLOPE 0-6% FS: SEVERE-TOO SANDY 6+% FS: SEVERE-SLOPE,TOO SANDY
PICNIC AREAS	LFS: MODERATE-TOO SANDY FS: SEVERE-TOO SANDY	PATHS AND TRAILS	LFS: MODERATE-TOO SANDY FS: SEVERE-TOO SANDY

CAPABILITY AND YIELDS PER ACRE OF CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY		GRAIN SORGHUM (BU)		IMPROVED BERMUDAGR. (AUM)											
	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
0-8% FS	4S		30		6.0											
0-3% LFS	3S		40		5.5											
3-8% LFS	3E		30		6.0											

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	COMMON TREES	SITE INDX	TREES TO PLANT
							NONE		

(MANAGEMENT PROBLEMS: EROSION HAZARD through PLANT COMPET.; POTENTIAL PRODUCTIVITY: COMMON TREES, SITE INDX)

WINDBREAKS

CLASS-DETERMIN'G PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (C)

CLASS-DETERMINING PHASE	POTENTIAL FOR HABITAT ELEMENTS								POTENTIAL AS HABITAT FOR:			
	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
ALL	POOR	POOR	FAIR	POOR	POOR	GOOD	POOR	V. POOR	POOR	POOR	V. POOR	FAIR

POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION) (D)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	PERCENTAGE COMPOSITION (DRY WEIGHT) BY CLASS DETERMINING PHASE: ALL				
LITTLE BLUESTEM	ANSC2	50				
INDIANGRASS	SONU2	10				
CRINKLEAWN	TRSE	5				
PURPLETOP	TRFL2	5				
SWITCHGRASS	PAVI2	5				
FRINGELEAF PASPALUM	PACI2	5				
POST OAK	QUST	5				
BLACKJACK OAK	QUMA3	5				
OTHER ANNUAL GRASSES	AAGG	5				
OTHER PERENNIAL FORBS	PPFF	5				
POTENTIAL PRODUCTION (LBS./AC. DRY WT):						
FAVORABLE YEARS		4500				
NORMAL YEARS		4000				
UNFAVORABLE YEARS		2000				

FOOTNOTES

A ESTIMATES OF ENGINEERING PROPERTIES BASED ON TEST DATA OF 3 PEDONS FROM CALDWELL COUNTY, TEXAS.
B RATINGS BASED ON NATIONAL SOILS HANDBOOK, SEC. 403.
C WILDLIFE RATINGS BASED ON SOILS MEMORANDUM-74, JAN. 1972.
D "SANDY" RANGE SITE.

Established Series
Rev. ALN:CLG
5/73

TARRANT SERIES

The Tarrant series is a member of the clayey-skeletal, montmorillonitic, thermic family of Lithic Calciustolls. These soils have very dark grayish brown to dark brown clayey A horizons containing about 55 percent of limestone fragments, resting on indurated limestone bedrock at about 13 inch depth.

Typifying Pedon: Tarrant cobbly clay - native pasture.
(Colors are for dry soil unless otherwise stated.)

A11 -- 0-8 inches, very dark grayish brown (10YR 3/2) cobbly clay; very dark brown (10YR 2/2) moist; compound strong very fine subangular blocky and strong medium granular structure; very hard, firm; common fine roots; common fine pores; about 35 percent by volume of cobblestones and 5 percent pebble size fragments of limestone; stone fragments are randomly oriented and coated with secondary calcium carbonate; calcareous; moderately alkaline; clear irregular boundary. (4 to 10 inches thick)

A12ca -- 8-13 inches, dark brown (10YR 4/3) cobbly clay, dark brown (10YR 3/3) moist, occupies about 15 percent by volume in vertical bands as much as 2 inches wide and horizontal bands as much as 1 inch wide; compound moderate very fine blocky and moderate medium granular structure; very hard, firm; common fine roots in both vertical and horizontal bands; calcareous; moderately alkaline; 85 percent by volume of cobblestone and stone-size fragments of limestone that have thin patchy calcium carbonate coatings and pendants; abrupt wavy boundary. (2 to 10 inches thick)

R -- 13-30 inches, fractured indurated and platy limestone bedrock and strata of strongly to weakly cemented limestone about 1/2 to 6 inches thick; about 1 percent by volume brown (10YR 4/3) clay, dark brown (10YR 3/3) moist, in vertical and horizontal bands 1/32 to 1/2 inch wide; moderate very fine subangular blocky structure; very hard, firm; few fine roots extend into the crevices and clay between the plates of the limestone; thin patchy calcium carbonate coating on limestone plates.

Type Location: Menard County, Texas; in native pasture 150 feet west of edge of U.S. Highway 83 1.2 miles south of the intersection of U.S. Highway 83 and Ranch Road 2291 in Menard.

Range in Characteristics: Thickness of the solum ranges from 6 to 20 inches, and corresponds to the depth to indurated limestone. The solum contains 35 to 85 percent coarse fragments, the amount ranging from 10 to 60 percent in the A11 horizon and from 70 to 90 percent in the A12 horizon. Coarse fragments are dominantly limestone but some pedons include quartziferous fragments. The fragments greater than 3 inches in diameter comprise 25 to 70 percent of the soil. Fragments less than 3 inches in diameter are mostly larger than 0.75 inch in diameter. Secondary coating of $CaCO_3$ on the fragments is lacking in the upper 4 inches of some pedons, but is 1 cm. or more thick on some fragments immediately above the R layer. Carbonates are in the form of coatings and pendants.

The A horizon is dark brown (10YR 4/3, 3/3; 7.5YR 4/2, 3/2), dark grayish brown (10YR 4/2), very dark grayish brown (10YR 3/2) or very dark brown (7.5YR 2/2; 10YR 2/2). It is cobbly clay or cobbly silty clay, containing 40 to 60 percent clay in the fine earth fraction. The strata of the underlying fractured bedrock range in thickness from 2 to 24 inches. In some pedons, massive pulverulent lime is interbedded with the bedrock.

Competing Series and their Differentiae: These are the Eckrant, Ector, Eddy, Kavett, Maloterre, Purves, Talpa, and Yates series. All these soils except Eckrant and Purves soils have less than 35 percent clay in the fine earth fraction. Eckrant soils lack calcic horizons and Purves soils, as well as Kavett, Maloterre, and Talpa soils, have less than 35 percent coarse fragments in their control sections. Ector and Maloterre soils have carbonatic mineralogy. Eddy and Yates soils, as well as Maloterre soils, have ochric epipedons.

Setting: Tarrant soils are on convex to plane slopes of ridgetops and breaks of erosional uplands. Slopes are mainly 1 to 8 percent, but some are as much as 50 percent. The soil formed in residuum weathered mainly from limestone of lower Cretaceous age, and includes interbedded chalks, marls, and marly earths. The mean annual precipitation ranges from 22 to 34 inches, Thornthwaite annual P-E indices are about 30 to 56, and mean annual temperature is about 62° to 70° F.

Principal Associated Soils: These are the competing Kavett series, and the Brackett, Crawford, Denton, Tobosa, and Valera series. Crawford, Denton, Tobosa, and Valera soils are more than 20 inches deep. Brackett soils are light colored, shallow soils underlain by softer limestone.

Drainage and Permeability: Well drained; rapid runoff; moderately slow permeability.

Use and Vegetation: Used entirely as rangeland. The original vegetation included little bluestem. The present range is buffalograss, Texas wintergrass, green sprangletop, threeawn, panicum, agarito, pricklypear, a few mesquite, many live oak and yucca.

Distribution and Extent: West central Texas, and Oklahoma, mainly in the Edwards Plateau and the Grand Prairie, but some areas are on Pennsylvanian or Permian limestones in the same climatic zone. The series is extensive.

Series Established: McLennan County, Texas; 1945.

Remarks: These soils were classified as Lithosols in recently published surveys.

Additional Data: Lincoln Laboratory Sample Nos.-20207, 20208, 20209, 20210, 20225, 20226, 20227, [illegible], and 20229.

MLRA(S): 81, 78, 80, 85 — TARRANT SERIES
CLG,ALR, 5-73
LITHIC CALCIUSTOLLS, CLAYEY-SKELETAL, MONTMORILLONITIC, THERMIC

THE TARRANT SERIES CONSISTS OF WELL DRAINED, MODERATELY SLOWLY PERMEABLE CALCAREOUS SOILS ON UPLANDS. THESE SOILS DEVELOPED IN RESIDUUM WEATHERED MAINLY FROM LIMESTONE. IN A REPRESENTATIVE PROFILE THE SURFACE LAYER IS VERY DARK BROWN AND DARK BROWN CALCAREOUS COBBLY CLAY ABOUT 13 INCHES THICK UNDERLAID WITH FRACTURED PLATY LIMESTONE. SLOPES RANGE FROM 1 TO 50 PERCENT.

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-13	CB-C, CB-SIC	CH, GC	A-7-6	33-77	55-100	51-100	51-95	45-95	55-76	31-49
13-30	IND, UWB									

DEPTH (IN.)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	CORROSIVITY STEEL	CORROSIVITY CONCRETE	EROSION FACTORS K	T	WIND EROD. GROUP
0-13	0.2-0.6	0.10-0.17	7.9-8.4	-	LOW	HIGH	LOW	.32	1	-
13-30										

FLOODING FREQUENCY	FLOODING DURATION	FLOODING MONTHS	HIGH WATER TABLE DEPTH (FT)	HIGH WATER TABLE KIND	HIGH WATER TABLE MONTHS	CEMENTED PAN DEPTH (IN)	CEMENTED PAN HARDNESS	BEDROCK DEPTH (IN)	BEDROCK HARDNESS	SUBSIDENCE INIT. (IN)	SUBSIDENCE TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6			-		4-20	HARD	-		D	-

SANITARY FACILITIES (B)

SEPTIC TANK ABSORPTION FIELDS	1-15%: SEVERE-DEPTH TO ROCK 15-50%: SEVERE-DEPTH TO ROCK,SLOPE
SEWAGE LAGOON AREAS	1-7%: SEVERE-DEPTH TO ROCK 7-50%: SEVERE-DEPTH TO ROCK,SLOPE
SANITARY LANDFILL (TRENCH)	1-25%: SEVERE-DEPTH TO ROCK 25-50%: SEVERE-DEPTH TO ROCK,SLOPE
SANITARY LANDFILL (AREA)	1-8%: SLIGHT 8-15%: MODERATE-SLOPE 15-25%: SEVERE-SLOPE
DAILY COVER FOR LANDFILL	POOR-THIN LAYER,LARGE STONES,TOO CLAYEY

COMMUNITY DEVELOPMENT (B)

SHALLOW EXCAVATIONS	SEVERE-DEPTH TO ROCK
DWELLINGS WITHOUT BASEMENTS	SEVERE-DEPTH TO ROCK,LARGE STONES
DWELLINGS WITH BASEMENTS	SEVERE-DEPTH TO ROCK,LARGE STONES
SMALL COMMERCIAL BUILDINGS	SEVERE-DEPTH TO ROCK,LARGE STONES
LOCAL ROADS AND STREETS	SEVERE-DEPTH TO ROCK,LARGE STONES

REGIONAL INTERPRETATIONS

SOURCE MATERIAL (B)

ROADFILL	POOR-THIN LAYER,LARGE STONES
SAND	UNSUITED
GRAVEL	UNSUITED
TOPSOIL	POOR-THIN LAYER,LARGE STONES

WATER MANAGEMENT

POND RESERVOIR AREA	SEVERE-DEPTH TO ROCK
EMBANKMENTS DIKES AND LEVEES	SEVERE-THIN LAYER,LARGE STONES
EXCAVATED PONDS AQUIFIER FED	SEVERE-NO WATER
DRAINAGE	DEPTH TO ROCK
IRRIGATION	ROOTING DEPTH
TERRACES AND DIVERSIONS	DEPTH TO ROCK,LARGE STONES
GRASSED WATERWAYS	ROOTING DEPTH,LARGE STONES

RECREATION (C)

CAMP AREAS	1-15%: SEVERE-LARGE STONES,TOO CLAYEY 15-50%: SEVERE-LARGE STONES,SLOPE	PLAYGROUNDS	1-6%: SEVERE-DEPTH TO ROCK,LARGE STONES 6-50%: SEVERE-DEPTH TO ROCK,SLOPE
PICNIC AREAS	SEVERE-LARGE STONES,TOO CLAYEY	PATHS AND TRAILS	1-25%: SEVERE-LARGE STONES,TOO CLAYEY 25-50%: SEVERE-LARGE STONES,SLOPE

CAPABILITY AND PREDICTED YIELDS -- CROPS AND PASTURE (HIGH LEVEL MANAGEMENT)

CLASS-DETERMINING PHASE	CAPABILITY NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.	NIRR	IRR.
ALL	7S															

WOODLAND SUITABILITY

CLASS-DETERMINING PHASE	ORD SYM	EROSION HAZARD	EQUIP. LIMIT	SEEDLING MORT'Y.	WINDTH. HAZARD	PLANT COMPET.	IMPORTANT TREES	SITE INDX	TREES TO PLANT
							NONE		

WINDBREAKS

CLASS-DETERMINING PHASE	SPECIES	HT	SPECIES	HT	SPECIES	HT	SPECIES	HT
	NONE							

WILDLIFE HABITAT SUITABILITY (D)

CLASS-DETERMINING PHASE	GRAIN & SEED	GRASS & LEGUME	WILD HERB.	HARDWD TREES	CONIFER PLANTS	SHRUBS	WETLAND PLANTS	SHALLOW WATER	OPENLD WILDLF	WOODLD WILDLF	WETLAND WILDLF	RANGELD WILDLF
ALL	V. POOR	V. POOR	FAIR	-	POOR	FAIR	V. POOR	V. POOR	POOR	-	V. POOR	FAIR

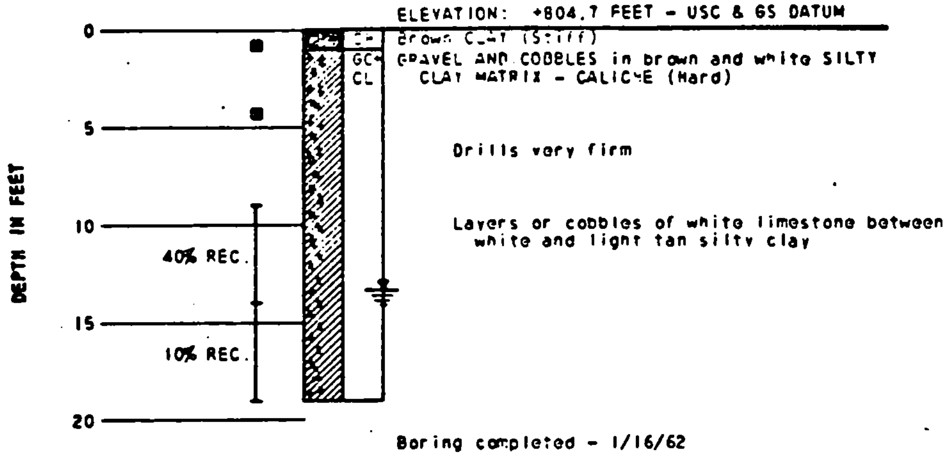
POTENTIAL NATIVE PLANT COMMUNITY (RANGELAND OR FOREST UNDERSTORY VEGETATION) (E)

COMMON PLANT NAME	PLANT SYMBOL (NLSPN)	1-8%	8-50%			
LITTLE BLUESTEM	ANSC2	15	10			
SIDEOATS GRAMA	BOCU	15	20			
BUFFALOGRASS	BUDA	5	-			
CURLYMESQUITE	HIBE	10	-			
GREEN SPRANGLETOP	LEDU	5	10			
TEXAS WINTERGRASS	STLE5	5	-			
TEXAS CUPGRASS	ERSE5	5	-			
TALL DROPSEED	SPAS	5	-			
INDIANGRASS	SONU2	-	5			
SILVER BLUESTEM	ANSA	5	15			
FALL WITCHGRASS	LECO	-	5			
LIVE OAK	QUVI	5	5			
OTHER PERENNIAL GRASSES	PPGG	10	10			
OTHER SHRUBS	SSSS	5	10			
OTHER PERENNIAL FORBS	PPFF	10	10			
POTENTIAL PRODUCTION (LBS./AC. DRY WT): FAVORABLE YEARS		2500	1800			
NORMAL YEARS		1800	1400			
UNFAVORABLE YEARS		1200	800			

FOOTNOTES

A ESTIMATES OF ENGINEERING PROPERTIES BASED ON TEST DATA OF 5 PEDONS FROM MENARD AND TRAVIS COUNTIES, TEXAS.
B RATINGS BASED ON "GUIDE FOR INTERPRETING ENGINEERING USES OF SOILS", NOV. 1971.
C RECREATION RATINGS BASED ON SOILS MEMORANDUM-69, OCT. 1968.
D WILDLIFE RATINGS BASED ON SOILS MEMORANDUM-74, JAN. 1972.
E LOW STONY HILLS RANGE SITE-1-8%; STEEP ROCKY RANGE SITE-8-50%.
1 RATINGS BASED ON SRWPC COMMITTEE IV GUIDE, DRAFT APR. 1970.

BORING I



LOG OF BORING

KEY:

A - B ■ C

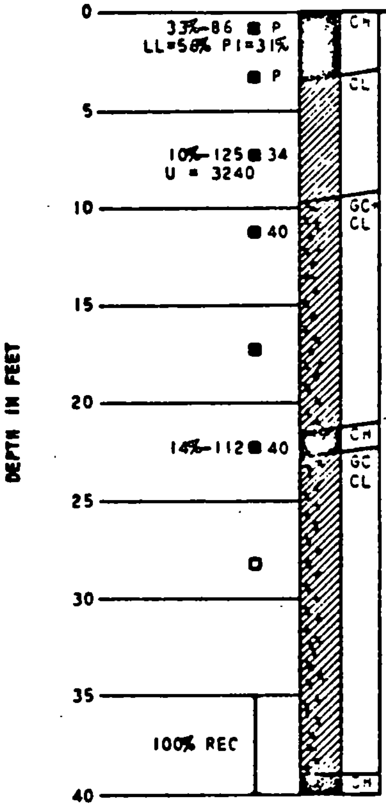
A FIELD MOISTURE EXPRESSED AS A PERCENTAGE OF THE DRY WEIGHT OF SOIL
B DRY DENSITY EXPRESSED IN LBS./CU. FT.
C BLOWS PER FOOT OF PENETRATION WITH A 500 LB. HAMMER DROPPING 36" - P = PUSH
LL = LIQUID LIMIT
PI = PLASTICITY INDEX
U = UNCONFINED COMPRESSIVE STRENGTH IN LBS./SQ. FT.

◘ DEPTH OF DISTURBED SAMPLE
□ DEPTH OF SAMPLING ATTEMPT WITH NO RECOVERY
■ DEPTH OF UNDISTURBED SAMPLE
I DEPTH AND LENGTH OF CORING RUN

BORING LOCATIONS AND ELEVATIONS SHOWN ARE APPROXIMATE. FINAL BORING LOCATIONS AND ELEVATIONS ARE BEING SURVEYED AND WILL BE PRESENTED ON DRAWINGS OF THE RALPH M. PARSONS COMPANY.

DAMES & MOORE
APPLIED EARTH SCIENCES

BORING 2



Black and brown CLAY (Moderately soft)

Brown and tan SILTY CLAY (Firm)

Grading to include cemented lumps - Caliche (Very firm)
Drills very firm

Brown and white CLAY AND GRAVEL with thin tan limestone slabs - CALICHE

Fractures at 14'

Tan CLAY with slab limestone (Very firm)

LIMESTONE layers with firm CLAY in between the layers

Firm clay layers appear to be less than 3" thick

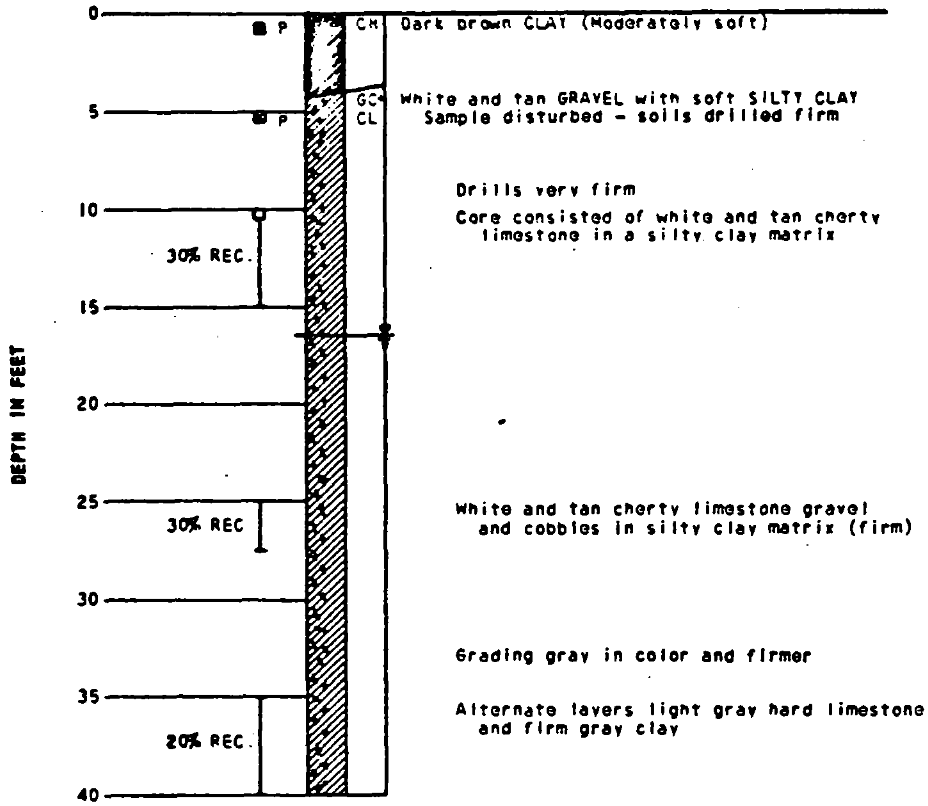
Becoming firmer

Gray firm CLAY interbedded with hard gray limestone

Boring completed - 1/13/62
Water table not measured (Erratic readings)

LOG OF BORING

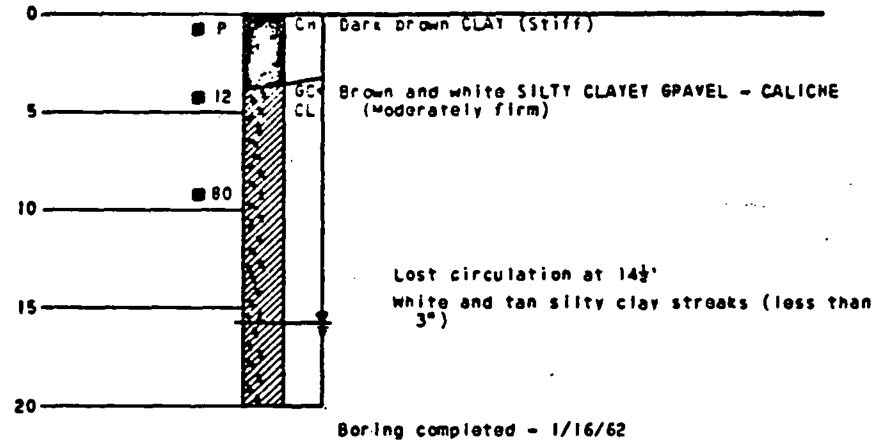
BORING 3



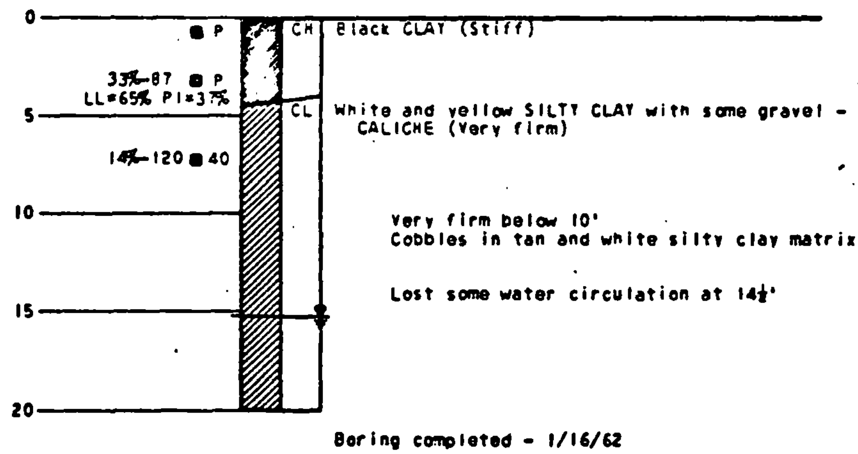
Boring completed - 1/15/62

LOG OF BORING

BORING 4

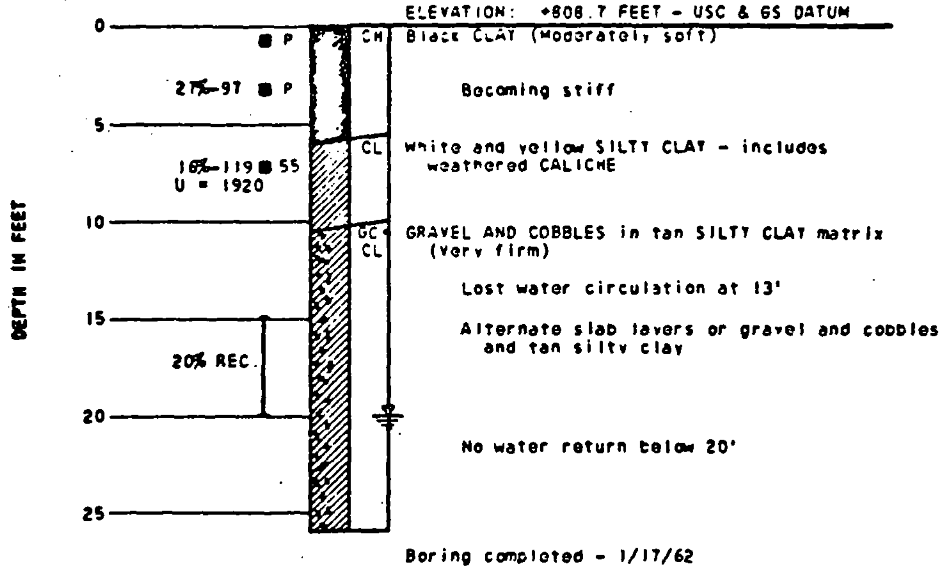


BORING 5

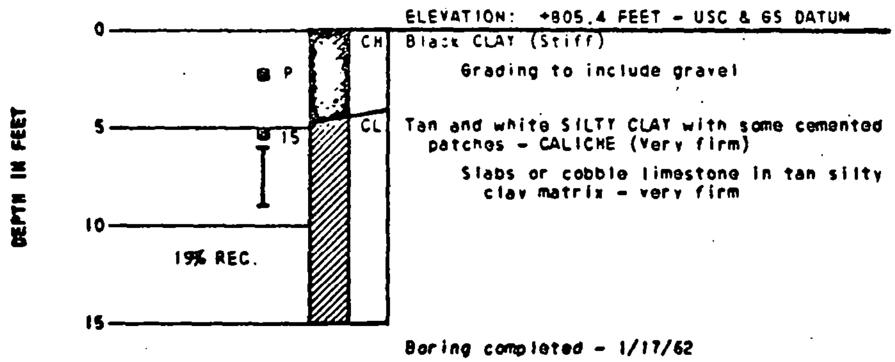


LOG OF BORINGS

BORING 6



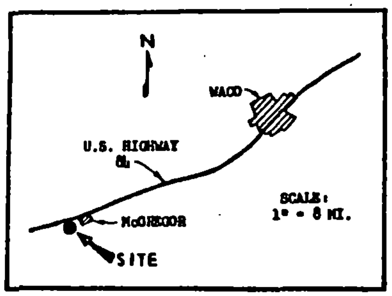
BORING 7



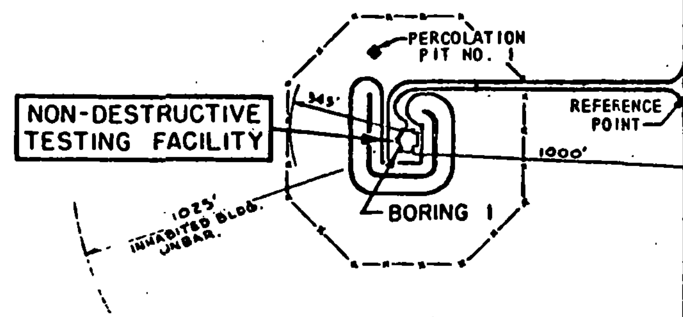
LOG OF BORINGS

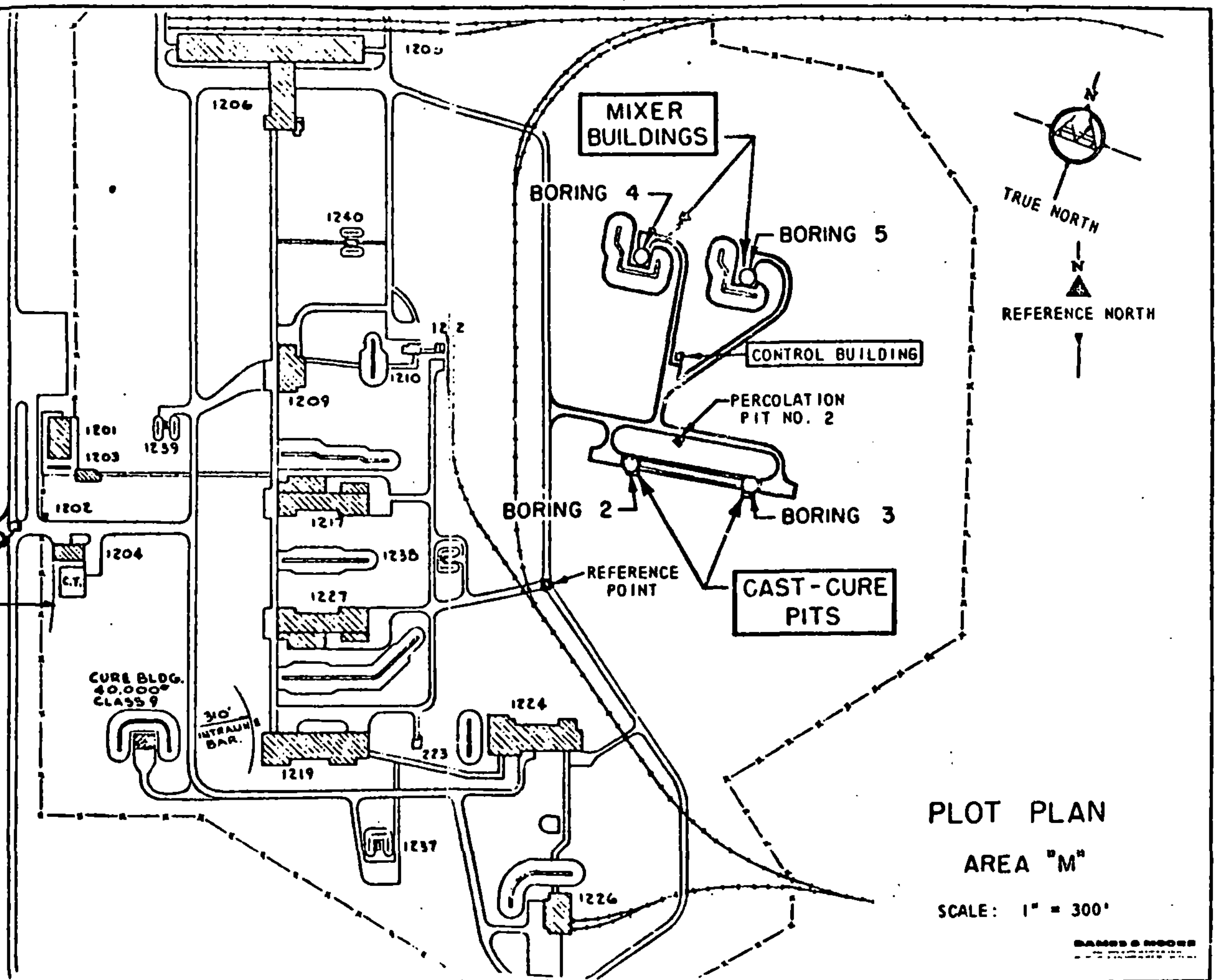
DAMES & MOO

APPLIED EARTH SCIENCES



VICINITY MAP





BORING LOCATIONS AND ELEVATIONS SHOWN ARE APPROXIMATE. FINAL BORING LOCATIONS AND ELEVATIONS ARE BEING SURVEYED AND WILL BE PRESENTED ON DRAWINGS OF THE RALPH M. PARSONS COMPANY.

REFERENCE:
DRAWING TITLED "FACILITIES EXPANSION LAYOUT, AREA M" MADE BY ROCKETDYNE, McGREGOR, TEXAS; DRAWING NO. 61XF-009, DATED 11-16-61.

LOCATIONS OF BORINGS FROM REFERENCE POINTS

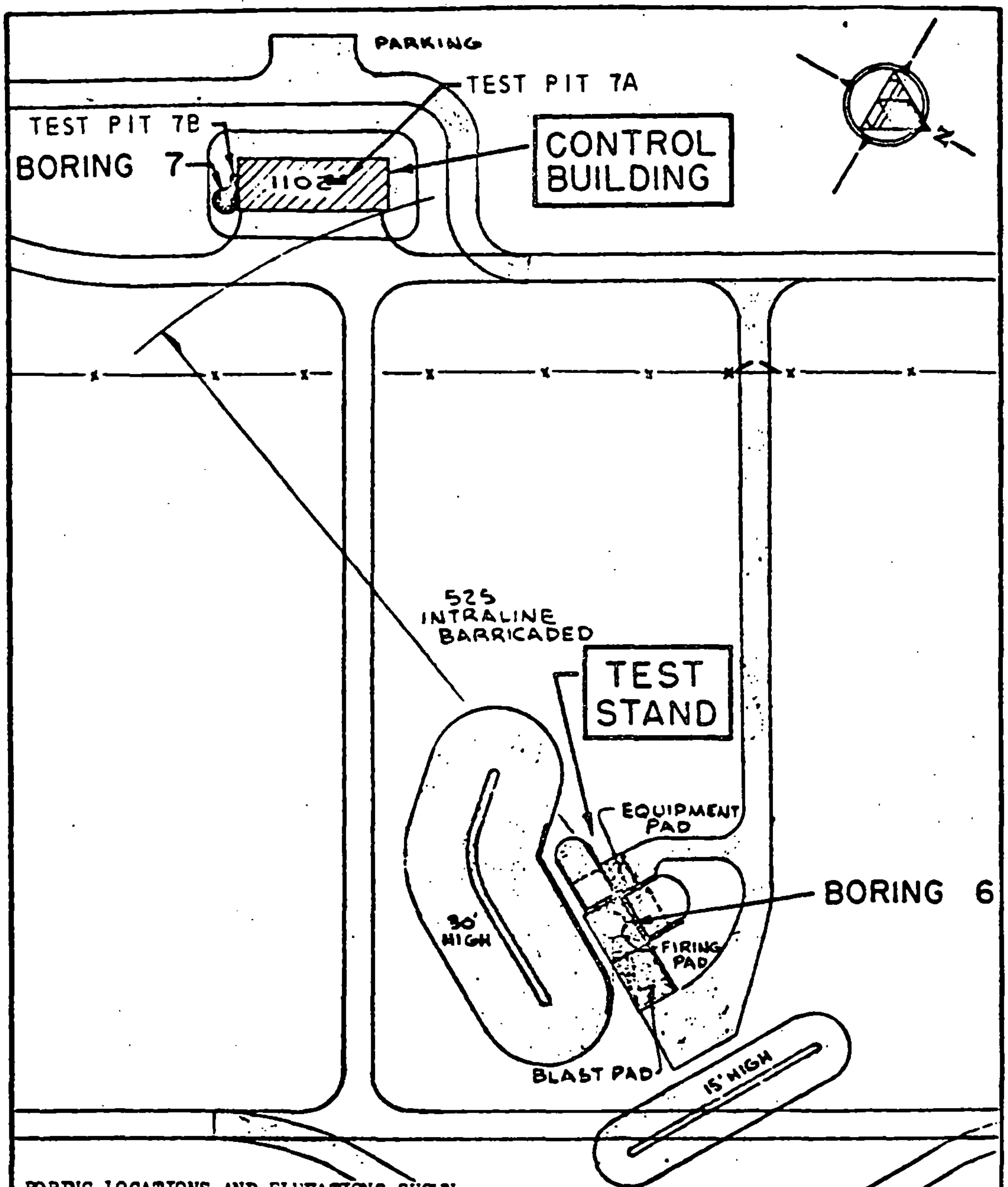
BORING NO.	DISTANCE AND DIRECTION
1	900' W.-170' S.
2	265' E.-318' N.
3	638' E.-250' N.
4	342' E.-968' N.
5	680' E.-904' N.

DISTANCES REFER TO "REFERENCE NORTH" DIRECTION

FORM NO. 946.7 (REV. 2-61)

PLATE 1

BORING LOCATION MAP FOR BORINGS 1-5



BORING LOCATIONS AND ELEVATIONS SHOWN ARE APPROXIMATE. FINAL BORING LOCATIONS AND ELEVATIONS ARE BEING SURVEYED AND WILL BE PRESENTED ON DRAWINGS OF THE RALPH M. PARSONS COMPANY.

REFERENCE:
DRAWING TITLED "PROPOSED LOCATION PLAN" MADE BY ROCKETDYNE, McGREGOR, TEXAS; DRAWING NO. 61XB-090, DATED 11-30-61.

PLOT PLAN
AREA "L"
SCALE: 1" = 100'

DAMES & MOORE

BORING LOCATION MAP FOR BORINGS 6 AND 7

APPENDIX B
GROUNDWATER BACKGROUND DATA

Drillers' Logs of Selected Wells in McLennan County—Continued

Well ST-40-37-802

Owner: North American Rockwell Corp., Rocketdyne Div.
Driller: Layne Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Black dirt	1	1
Hard, white lime	22	23
Blue-white lime	12	35
Gray lime and shale	77	112
Light gray lime	38	150
Hard, white lime	18	168
Hard, gray lime	32	200
Gray lime and shale	15	215
Hard, gray lime	30	245
White lime	12	257
Gray lime and shale	33	290
Blue shale and lime	101	391
Hard, gray lime and shale	51	442
Sandy lime and shale	28	470
Hard, gray lime and shale	35	505
White shale and gray lime	28	533
Gray, sandy lime	24	557
Dark gray shale and lime	23	580
Gray lime and shale	15	595
Gray, sandy lime	37	632
Gray, sandy lime and shale	68	700
Soft shale and lime	45	745
Gray, sandy lime	35	780
Gray, sandy lime and shale	80	860
Gray shale and lime	49	909
Gray, sandy lime	10	919
Hard, gray lime and shale	15	934
Green shale and lime	15	949
Gray, sandy lime and green shale	11	960
First Trinity sand	56	1,006
Trinity sand and blue shale	13	1,019
Sandy, blue shale	25	1,044
Gray, sandy lime and shale	2	1,046

Well ST-40-37-803

Owner: North American Rockwell Corp., Rocketdyne Div.
Driller: Layne Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Black dirt	4	4
Lime shales and clay	21	25
Gray lime	18	43
Gray lime and shale	24	67
Hard, gray lime	55	122
White lime	28	150
Hard, gray lime	23	173
Gray lime and shale	22	195
Gray shale	20	215
Gray lime and shale	30	245
Light lime and shale	22	267
Dark lime and shale	30	297
Blue shale	33	330
Lime and flintrock	5	335
Hard, blue lime	33	368
Gray lime and shale	107	475
Gray, sandy lime	26	501
Gray lime and shale	99	600
Gray, sandy lime and shale	65	665
Gray lime and shale	135	800
Dark lime and shale	75	875
Gray lime and shale	17	892
Hard, gray lime	23	915
Gray, sandy lime and shale	15	930
Hard, gray lime	25	955
Dark lime and shale	7	962
Trinity sand	30	992
Sand and breaks of shale	21	1,013
Went out of sand at 1,010 ft marking 48 ft of sand	—	—
Dark shale and lime	47	1,060
Red shale	5	1,065
Gray lime and shale	16	1,081
Hard, gray lime	19	1,100
Hard, dark lime	101	1,201

	THICKNESS (FEET)	DEPTH (FEET)

Well ST-40-37-804

Owner: North American Rockwell Corp., Rocketdyne Div.
Driller: Layne Texas Co.

Black soil	3	3
Yellow clay	4	7
Hard lime	23	30
Hard lime (gray) and shale	97	127
Hard limestone	5	132
Edwards lime	6	138
White lime	12	150
Hard, gray lime and shale	55	205
Gray shale	5	210
Dark lime and shale	80	290
Blue shale and lime	15	305
Lime and flint rock	10	315
Dark shale	5	320
Lime and shale	45	365
Gray shale and lime	10	375
Sandy lime and shale	10	385
Lime and shale	53	438
Gray shale and lime	32	470
Gray, sandy lime and shale breaks	63	533
Dark lime and shale	7	540
Light lime and shale	15	555
Dark shale and lime	10	565
Sandy lime and shale	135	700
Dark shale and lime	5	705
Gray shale and lime	25	730
Gray, sandy lime and blue shale	90	820
Soft, light, sandy shale	15	835
Dark lime and shale	10	845
Hard, gray lime and shale	31	876
Hard, gray lime	14	890
Gray, sandy lime and shale	30	920
Dark lime and shale	37	957
Trinity sand (good)	100	1,057
Dark shale and lime	5	1,062

Well ST-40-37-801

Owner: North American Rockwell Corp., Rocketdyne Div.
Driller: Layne Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Rock and white lime	7	7
Lime, shell, and clay	13	20
Blue-gray lime	12	32
Gray lime and shale	88	120
Dark and white lime	5	125
Hard, white lime	17	142
Dark white lime	6	148
Hard, gray lime	39	187
Gray lime and shale	23	210

Well ST-40-37-801—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Hard, gray lime	38	248
White lime and shale	9	257
Dark gray shale and lime	28	285
Blue shale and breaks of lime	36	321
Hard, gray lime	14	335
Blue shale and lime	9	344
Hard, gray lime	27	371
Blue shale and lime shells	22	393
Hard lime and shells	47	440
Gray, sandy lime	28	468
White shale and gray lime	35	503
Blue shale and lime	7	510
Gray, sandy lime	51	561
Dark gray shale and lime	8	569
Gray lime and shale	33	602
Light gray, sandy lime	33	635
Broken sand	16	651
Gray, sandy lime	49	700
Soft, shell lime	18	718
Light, sandy lime - soft shell	34	752
Hard, sandy lime	46	798
Hard lime and shale	14	812
Gray, sandy lime	18	830
Gray shale and lime	80	910
Gray, sandy shale	11	921
Hard, gray lime	6	927
Gray shale and lime	19	946
Hard gray lime	20	966
Green shale	5	971
First Trinity water sand	51	1,022
Sandy shale	25	1,047
Gray, sandy lime	18	1,065
Fine, sandy lime	13	1,078
Gray lime	11	1,089
Dark, sandy lime	24	1,113
Dark, cave shale and lime	77	1,190

MC LENNAN COUNTY

Chemical Analyses of Water From Selected Wells

WELL	DEPTH OF WELL (ft)	DATE OF COLLECTION	WATER BEARING UNIT	SILICA (SiO_2)	IRON (Fe)	CALCIUM (Ca)	MAGNESIUM (Mg)	SODIUM (Na)	POTASSIUM (K)	BICARBONATE (HCO_3)	SULFATE (SO_4)	CHLORIDE (Cl)	FLUORIDE (F)	NITRATE (NO_3)	BORON (B)	DISSOLVED SOLIDS REPORTED	DISSOLVED SOLIDS RECALCULATED	TOTAL HARDNESS AS $CaCO_3$	PERCENT SODIUM	SPECIFIC CONDUCTANCE (MICROMHOS AT 25° C)	pH	SODIUM ADSORPTION RATIO (SAR)
ST-40-32-104	2,329	Dec. 10, 1960	Kho	--	0.10	2.2	10	219.91	1.62	327	120	45	0.09	0.054	--	694	560	15.4	91	--	8.45	14.1
104	2,329	Mar. 21, 1962	do.	--	.08	4	2	240	--	425	115	44	1.2	1.1	--	642	616	18	97	1,010	8.1	24.9
104	2,329	Feb. 14, 1966	do.	--	< .02	4	1	243	--	418	127	41	1.4	< .4	--	840	624	14	97	1,116	8.4	28.6
106	2,255	Aug. 6, 1965	Ktp	--	1.05	4	1	231	--	409	--	--	1.1	< .4	--	810	--	13	97	1,098	8.7	27.2
403	2,312	Mar. 31, 1949	Kho	20	.08	3	1.5	239	6.8	428	88	53	1.4	.0	0.21	629	--	14	96	1,010	8.4	28.1
405	2,147	Mar. 23, 1937	Ktp	--	--	--	--	--	--	454	81	54	--	--	--	--	--	--	--	--	--	--
405	2,147	Jan. 9, 1943	do.	17	.01	3.3	1.3	237	1	339	86	52	.7	.2	--	633	566	14	97	--	8.4	27.9
501	2,493	Jan. 6, 1964	Kho	13.6	.7	3.2	1	252	--	423.3	98	60	.96	--	--	723.2	638	12	98	--	8.4	31.3
37-501	1,340	July 7, 1965	Kho	--	.10	5	1	247	--	434	120	46	1.9	< .4	--	860	634	19	97	1,150	8.5	26.9
601	1,028	Jan. 6, 1943	do.	10	.0	6.3	4.6	* 309	--	444	214	67	1	.5	--	844	831	34	95	--	8.2	22.8
601	1,028	Dec. 15, 1953	do.	26	.06	6	12	299	--	458	235	67	1.4	.4	--	897	872	65	91	--	8.5	16.3
602	1,250	Jan. 6, 1943	Kho, Kpe	13	.0	5.6	2.4	276	4.6	446	123	66	1.7	.0	--	736	712	24	95	--	8.4	24.5
602	1,250	June 20, 1951	do.	12	.04	7	3	* 261	--	476	127	61	1.2	< .4	--	624	707	35	95	--	8.2	20.6
603	1,028	Apr. 6, 1956	Kho	12	.16	3	2	256	--	421	127	53	1.1	< .4	--	685	662	16	97	--	8.4	27.8
603	1,028	Feb. 3, 1965	do.	--	< .02	4	2	247	--	446	130	43	1.2	< .4	--	860	647	18	97	--	8.4	25.6
604	1,044	Feb. 2, 1956	do.	10	.12	7	2	293	--	433	170	92	1.2	< .4	--	756	789	26	96	--	7.8	25.5
801	1,190	Aug. 5, 1942	do.	13	.18	11	6	* 264	--	384	142	64	1.4	.4	--	702	671	52	91	--	8.4	14.7
801	1,190	May 25, 1945	do.	20	.24	8	2	* 263	--	418	136	67	1.1	.4	--	722	704	28	95	--	8.3	21.6
801	1,190	Jan. 17, 1956	do.	12	.6	4	3	287	--	445	150	82	1.6	< .4	--	766	--	23	97	--	8.5	26.0
801	1,190	Nov. 1, 1961	do.	--	.08	5	1	274	--	461	107	62	1.2	< .4	--	699	678	16	97	1,165	8.3	29.8
802	1,046	Aug. 5, 1942	do.	15	.8	12	5	* 242	--	403	136	53	1	.4	--	678	663	51	91	--	8.3	14.6
802	1,046	May 25, 1945	do.	17	.07	7	2	* 264	--	421	138	64	.9	.4	--	724	700	26	96	--	8.3	23.0
802	1,046	Jan. 21, 1956	do.	12	.05	4	2	280	--	445	131	82	1.2	< .4	--	740	--	18	97	--	8.3	29.0
803	1,201	Aug. 28, 1942	do.	14	.24	8	4	* 250	--	403	131	67	.6	.7	--	684	--	37	94	--	8.3	18.1
803	1,201	May 25, 1945	do.	25	.27	7	2	* 267	--	421	136	71	1	.6	--	728	717	26	96	--	8.3	22.8
803	1,201	Jan. 17, 1956	do.	14	.05	4	3	285	--	433	164	75	1.6	< .4	--	720	760	23	96	--	8.7	23.4
804	1,062	Aug. 7, 1942	do.	13	.24	9	4	* 252	--	397	141	67	1.4	.4	--	699	683	39	93	--	8.4	17.7
804	1,062	May 25, 1945	do.	17	.04	7	2	* 270	--	403	145	78	1	.4	--	727	--	26	96	--	8.3	23.5
804	1,062	Jan. 17, 1956	do.	14	.03	4	3	276	--	427	141	82	1.4	< .4	--	713	732	23	96	--	8.7	25.0
38-302	1,485	Feb. 27, 1942	Khe, Kpe Kho	--	.4	4.3	2.5	* 282	--	434	152	66	--	1	--	738	721	21	97	--	--	26.7
302	1,485	Oct. 9, 1942	do.	13	--	--	--	--	--	245	--	82	--	--	--	644	--	--	--	--	8.5	--
302	1,485	Jan. 6, 1943	do.	13	.0	5.6	2.2	* 286	--	443	160	64	1.4	.5	--	764	751	23	96	--	8.2	25.9
801	1,460	May 15, 1945	Khe, Kho	--	.16	5	3	295	--	471	149	67	.9	< .4	--	990	753	25	96	1,385	8.4	25.7

MC LENNAN COUNTY

Records of Selected Water Wells

WELL	OWNER	DRILLER	DATE COMPLETED	DEPTH OF WELL (ft)	CASING: DIAMETER (in.)	CASING: DEPTH (ft)	WATER BEARING UNIT	ALTITUDE OF LAND SURFACE (ft)	WATER LEVEL: ABOVE (+) OR BELOW LAND SURFACE DATUM (ft)	WATER LEVEL: DATE OF MEASUREMENT	METHOD OF LIFT	USE OF WATER	REMARKS
ST-40-37-603	City of McGregor	Harvey Meadows and Son Well Driller	1956	1,028	10 8	976 1,018	Kho	720	349	Feb. 7, 1958	Sub, E 50	P	Screened from 968 to 1,018 ft. Pumping level 556 ft at 275 gpm on Feb. 7, 1958. Pump set at 700 ft. Cemented from 976 ft to surface. 1/
604	North American Rockwell Corp., Rocketdyne Div.	Layne Texas Co.	1945	1,044	12 10 8	16 963 1,044	do.	745	280	Mar. 30, 1949	T, E 50	Ind	Completed from 960 to 1,015 ft. Pump set at 610 ft. Reported yield 160 gpm. Cemented Temp. 86°F. 1/
606	Central Bosque Water Supply Corp.	Harvey Meadows and Son Well Driller	1968	1,020	7	1,020	do.	685	400 322.4	Jan. 20, 1969 Apr. 10, 1969	Sub, E 15	P	Perforated from 950 to 1,020 ft. Pump set at 550 ft. Reported yield 12 gpm. Cemented from 950 ft to surface.
• 801	North American Rockwell Corp., Rocketdyne Div.	Layne Texas Co.	1942	1,190	10 8	971 1,190	do.	755	175 282 410	June 1942 1949 Feb. 24, 1965	T, E 100	Ind	Completed from 971 to 1,036 ft. Pumping level 610 ft at 300 gpm on Feb. 24, 1965. Pump set at 610 ft. Temp. 84°F. 1/
• 802	do.	do.	1942	1,046	10	960 1,046	do.	774	216 417	1942 Feb. 24, 1965	T, E 75	Ind	Completed from 959 to 1,044 ft. Pumping level 369 ft at 375 gpm in 1942. Pump set at 590 ft. Reported yield 280 gpm. Cemented. Temp. 86°F. 1/
• 803	do.	do.	1942	1,201	10 8	962 1,009	do.	781	297	Mar. 30, 1949	T, E 50	Ind	Screened from 968 to 1,009 ft. Pump set at 620 ft. Reported yield 200 gpm. Cemented Temp. 86°F. 1/
• 804	do.	do.	1942	1,062	10 8	957 1,062	do.	800	250 414	1942 Feb. 24, 1965	T, E 100	Ind	Completed from 959 to 1,060 ft. Pumping level 483 ft at 420 gpm on Feb. 24, 1965. Pump set at 610 ft. Cemented. Temp. 85°F. 1/
38-302	Universal Atlas Cement Co.	-- Cluck	1928	1,485	10 6 5	205 1,227 1,485	Kho, Kpa, Kho	570	24 55 150 187.54	June 20, 1938 Jan. 6, 1943 Nov. 9, 1964 Feb. 18, 1965	T, E 50	Ind	Perforated from 1,227 to 1,485 ft. Pump set at 300 ft. Reported yield 100 gpm. Temp. 95°F.
303	Brazos Concrete Products, Inc.	C. M. Stoner Drilling Co.	1965	1,440	4	1,440	Kho	535	200	Apr. 15, 1965	Sub, E 5	Ind	Completed from 1,380 to 1.440 ft. Pump set at 359 ft. Cemented from 1,380 ft to surface. 1/
502	J. B. Todd	J. L. Myers Sons	1930	1,190	5 4	400 1,190	Kho	617	--	--	C, E	D, S	Perforated from 1,150 to 1,190 ft. Well drilled to 1,435 ft and plugged back to 1,190 ft. 3/
801	Spring Valley Water Supply Corp.	C. M. Stoner Drilling Co.	1965	1,460	7	1,460	Kho, Kho	695	263.00 322.08	May 13, 1965 Mar. 7, 1969	Sub, E 15	P	Gun perforated with 41 shots 1,244 to 1,264, 1,372 to 1,390, 1.397 to 1.406, 1.412 to 1,424, 1,436 to 1,440, and 1,448 to 1,450 ft. Pumping level 119 ft at 80 gpm on May 14 1965. Pump set at 443 ft. Cemented from 1,460 ft to surface. Texas Water Development Board observation well. 1/ 3/ 4/
ST-40-39-101	Waco Syrian Association	J. L Myers Sons	1930	1,865	6 4 2	350 1,800 1,865	Kho	635	334.56	Apr. 1, 1965	Sub, E 2	P	Completed from 1,800 to 1,865 ft. Pump set at 450 ft. Reported yield 10 gpm. Cemented from 1,800 ft to surface. Temp. 75°F.
103	Luther Herring	Harvey Meadows and Son Well Driller	1947	1,570	10 5	915 1,570	Kho	663	180 284.39	Apr. 23, 1950 Mar. 15, 1966	Sub, E 2	D, S	Completed from 1,530 to 1,570 ft. Pumping level 480 ft at 7 gpm. Texas Water Development Board observation well. 1/ 4/
104	Midway School	J L. Myers Sons	1930	1,872	7 4	450 1,870	Kho	670	358 347 361.32	Mar. 6, 1964 Dec. 10, 1964 Apr. 1, 1965	N	N	Reported yield 90 gpm in 1964. Cemented. Abandoned. 1/ 3/
106	Midway Water Co.	C. M. Stoner Drilling Co.	1963	1,828	10 7	990 1,828	do.	655	300 335.55	Dec. 29, 1963 Apr. 1, 1965	Sub, E 100	P	Slotted from 1,727 to 1,827 ft. Pumping level 593 ft at 580 gpm on Apr. 1. 1963. Pump set at 700 ft. Reported yield 600 gpm. Cemented. Temp. 111°F. 3/ 3/